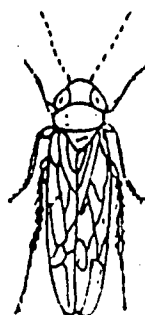


**A LABORATORY MANUAL
OF
INTRODUCTORY AGRICULTURAL ENTOMOLOGY**



Resham B Thapa
Fanindra P Neupane
Dhamo K Butani

DEPARTMENT OF PLANT PROTECTION
INSTITUTE OF AGRICULTURE AND ANIMAL SCIENCE
TRIBHUVAN UNIVERSITY
RAMPUR, CHITWAN, NEPAL.

PN-AT-904

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1984

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PREFACE

Insects are ubiquitous. There are about a million described species in this world and a large number still undescribed. A vast majority of them is no doubt harmless, a few even beneficial but about 2 percent species have been reported as destructive. They damage almost all our cultivated crops, contaminate stored food articles, annoy and sting man and the domesticated animals, and last but not the least, some insects act as vectors of viruses and other disease causing pathogens. That's why the insects are looked down upon as undesirable creatures and people often think of killing them.

To safe guard our plants and property from the ravages of insect pests, it is necessary to know all about these little beings. First and foremost step naturally is to collect the insects and study their appearance (morphology), physiology (function) and marks of identification (classification). With this aim in view, this manual is prepared to give the beginners a preliminary knowledge of introductory entomology as also some information about pesticides and their appliances. It covers the Core Course (ENT 3131) curriculum of the Institute of Agriculture and Animal Science, Rampur, Chitwan, Nepal.

It is not possible to include in this small manual all the information necessary for identifying the huge number of insect species, so it has been carried only upto Order and family level and that too by studying only the adult stage. To start with, only 12 most important orders have been dealt with.

The authors are grateful to Dean, IAAS, Rampur, Tribhuvan University, for the interest shown by him in preparing this manual. The help rendered by Mr. N.R.Devkota in drawing some of the diagrams as also the assistance and sincere efforts of Mr. Padam P Sharma and Ms. Laxmi Baral of IAAS Computer Centre, in word processing the manuscript in such a short time is highly appreciated. Thanks are also due to Dr. Herbert L. Whittier, Chief of Party, MUCIA and the IAAS/MUCIA/USAID Project for the encouragement and financial aid in printing this edition of the manual.

Suggestions, if any, for the improvement of this manual, are welcome.

August 21, 1984
IAAS, Rampur.

Resham B. Thapa
Fanindra P. Neupane
Dhamo K. Butari

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LAB EXERCISES

LAB 1: STUDY OF A MICROSCOPE

OBJECTIVE:

Microscopes are used for enlarging the image of a given object. The various appendages of insects being too small to study the same clearly with naked eyes, help of microscopes is sought to bring out the clarity and details, which facilitate the proper study of such parts.

MATERIALS:

1. Dissecting and binocular microscope
2. Occular and stage micrometers
3. Glass slides.

METHODS:

1. Take out microscope from cabinet using both hands, one on the bottom and other on the handle; keeping the microscope in straight position.
2. Place the microscope on the working table and arrange the light.

PROBLEMS:

1. Identify various parts of dissecting and binocular microscopes and label them in the diagrams (Fig. 1).
2. Calibrate occular and stage micrometer and measure the size of a given object.

- a. The index of occular micrometer in (power) of magnification.

S.N.	No. of division of occular micrometer	No. of divisions of stage micrometer
1		
2		
3		

Total

Average

b. Calculate the index of an ocular micrometer.

c. Measurement of a given specimen

Size of specimen..... in(power) of magnification.

No of divisions of ocular micrometer.

S.N.	Length	Width
1		
2		
3		

Total
Average

d. Calculate the actual size of the given specimen.

3. What are the precautions to be taken while handling a microscope?

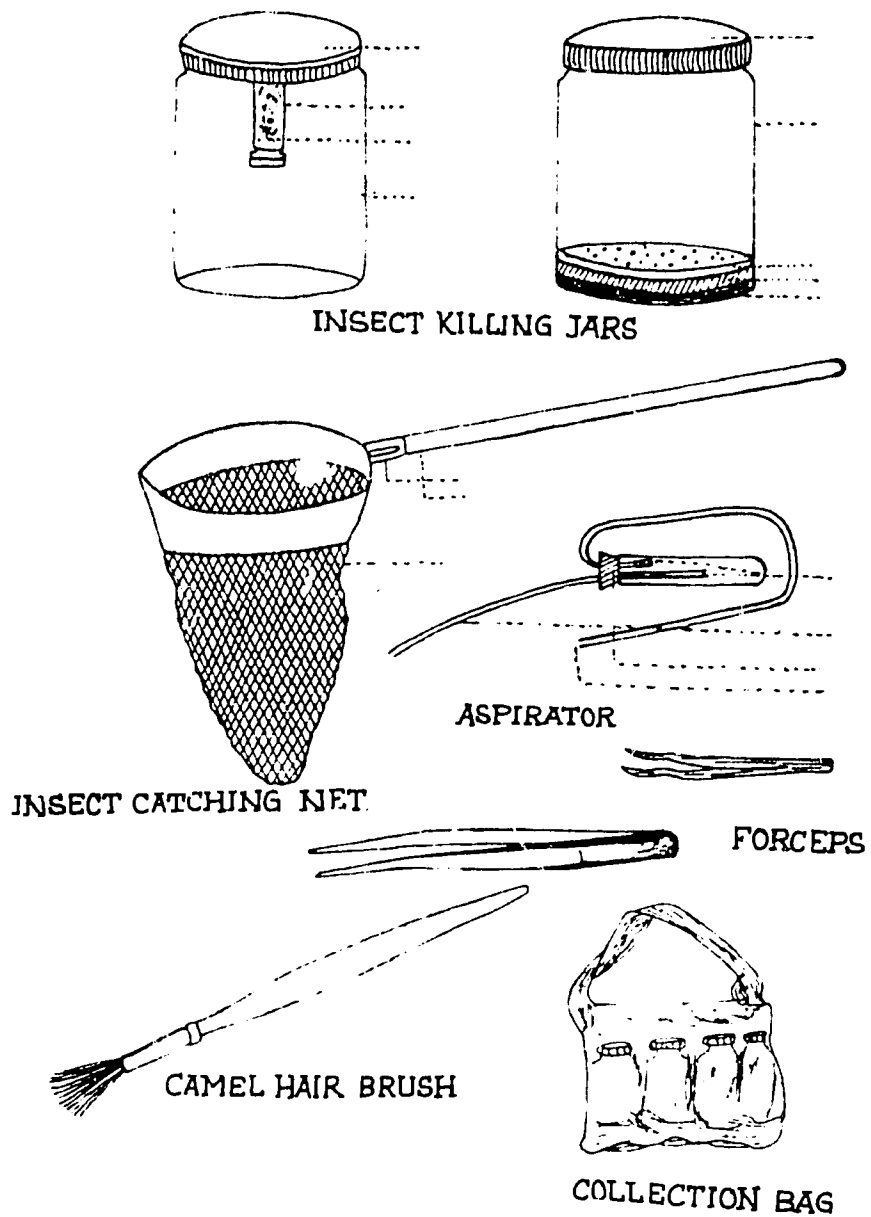


Fig.2. INSECT COLLECTING EQUIPMENT

LAB 2: COLLECTION AND PRESERVATION OF INSECTS

OBJECTIVE:

To study any object, first step is to collect that object. If the insect thus collected is to be kept for further studies, it should be properly killed, set and preserved, so that it does not get spoiled. Well preserved specimen can be seen in the museums where they may be lying for past several decades.

MATERIALS:

- | | |
|---------------------|----------------------|
| 1. Killing jar | 7. Fine thin pins |
| 2. Catching net | 8. Pinning block |
| 3. Forceps | 9. Collection box |
| 4. Camel hair brush | 10. Spreading boards |
| 5. Collection bag | 11. Labels |
| 6. Aspirator | 12. Collecting vials |
| | 13. Preservatives. |

METHODS: (For details refer to page 49)

1. Prepare an insect killing jar.
2. Identify the various materials required for collection and preservation.
3. Observe proper pinning position, setting on board and preservation of adults and immatures.

PROBLEMS:

1. Label the various parts (Fig. 2), proper pinning position (Fig. 3) and spreading board (Fig. 4).
2. Continue collecting, pinning and preserving insect specimens throughout the year. Mount properly and identify them.
3. What precautions will you take while preparing and using the insect killing jar?

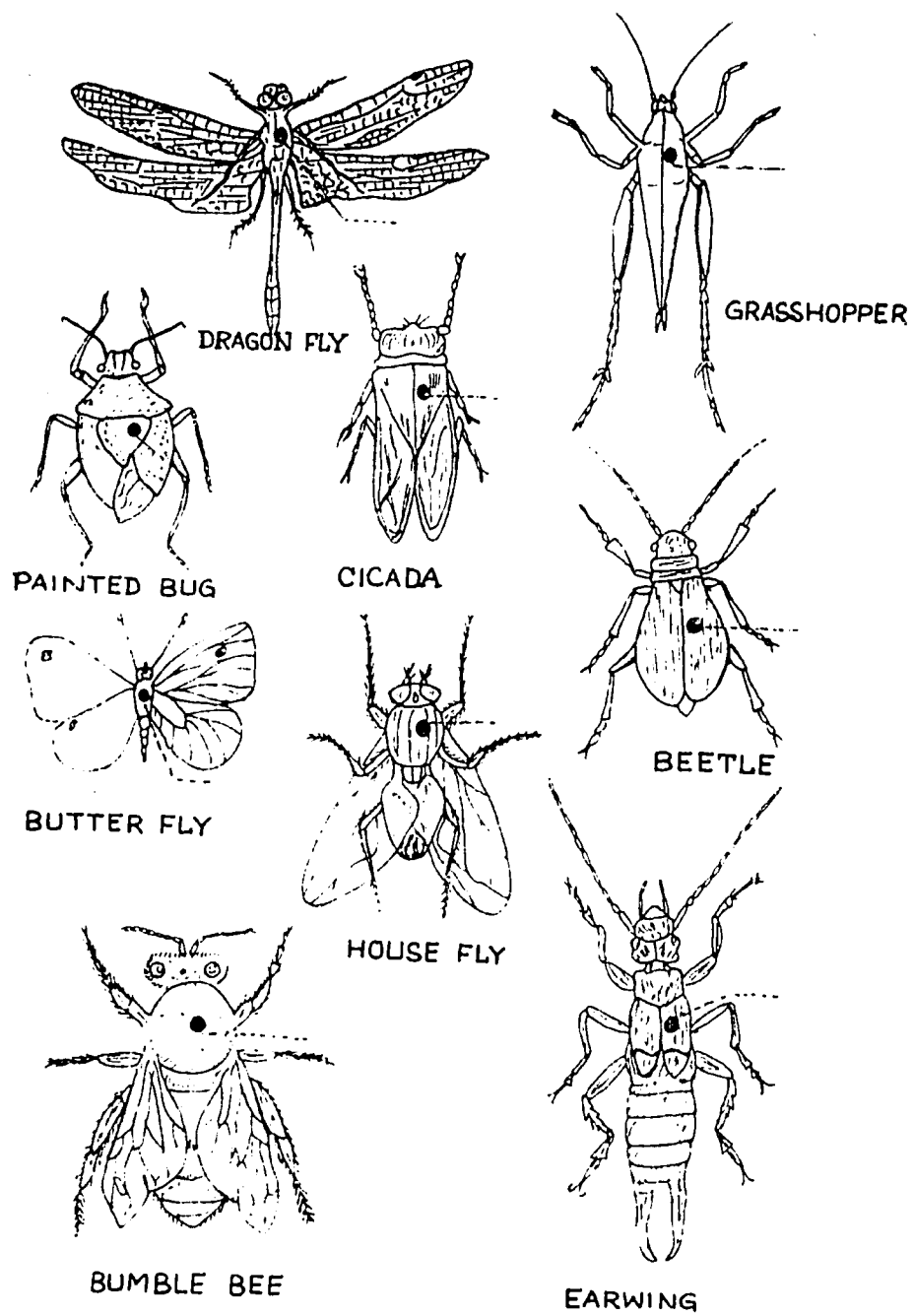


Fig.3 PINNING POSITIONS

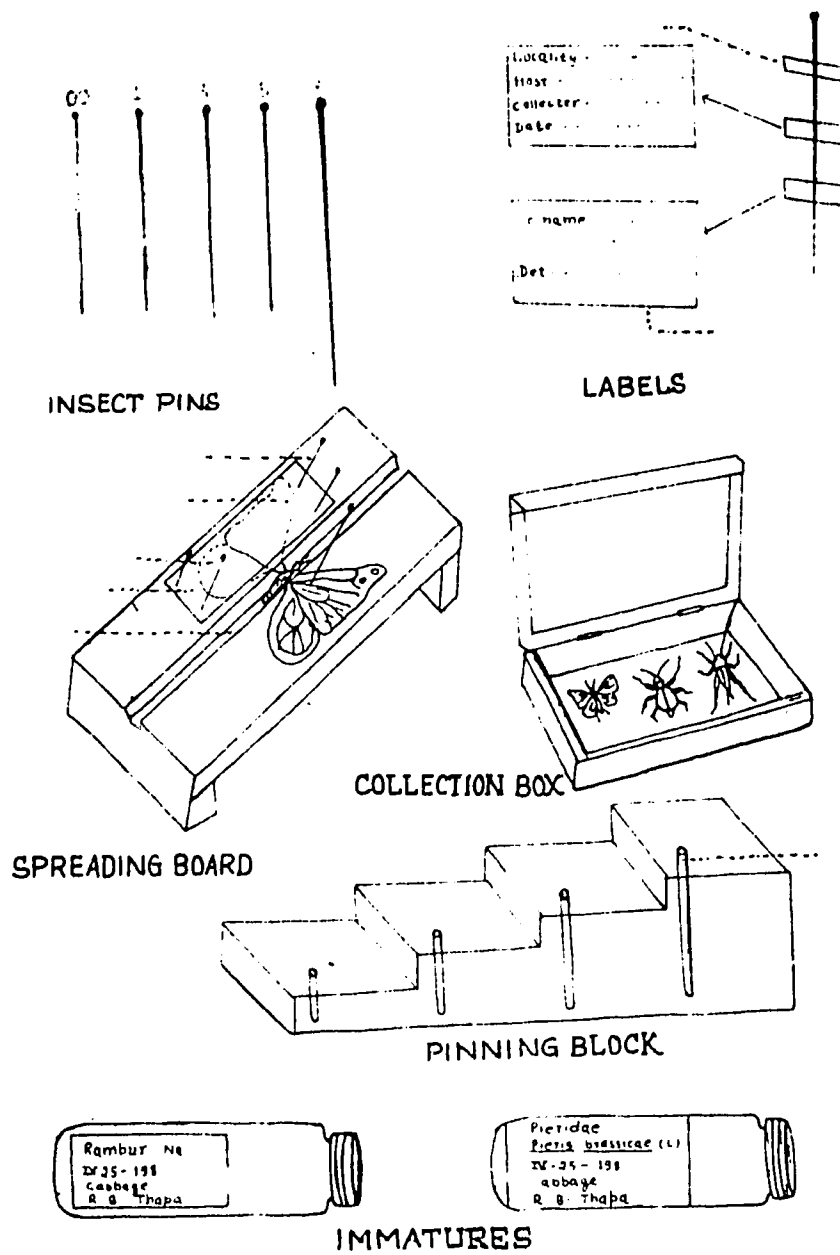


Fig.4. INSECT PRESERVATION

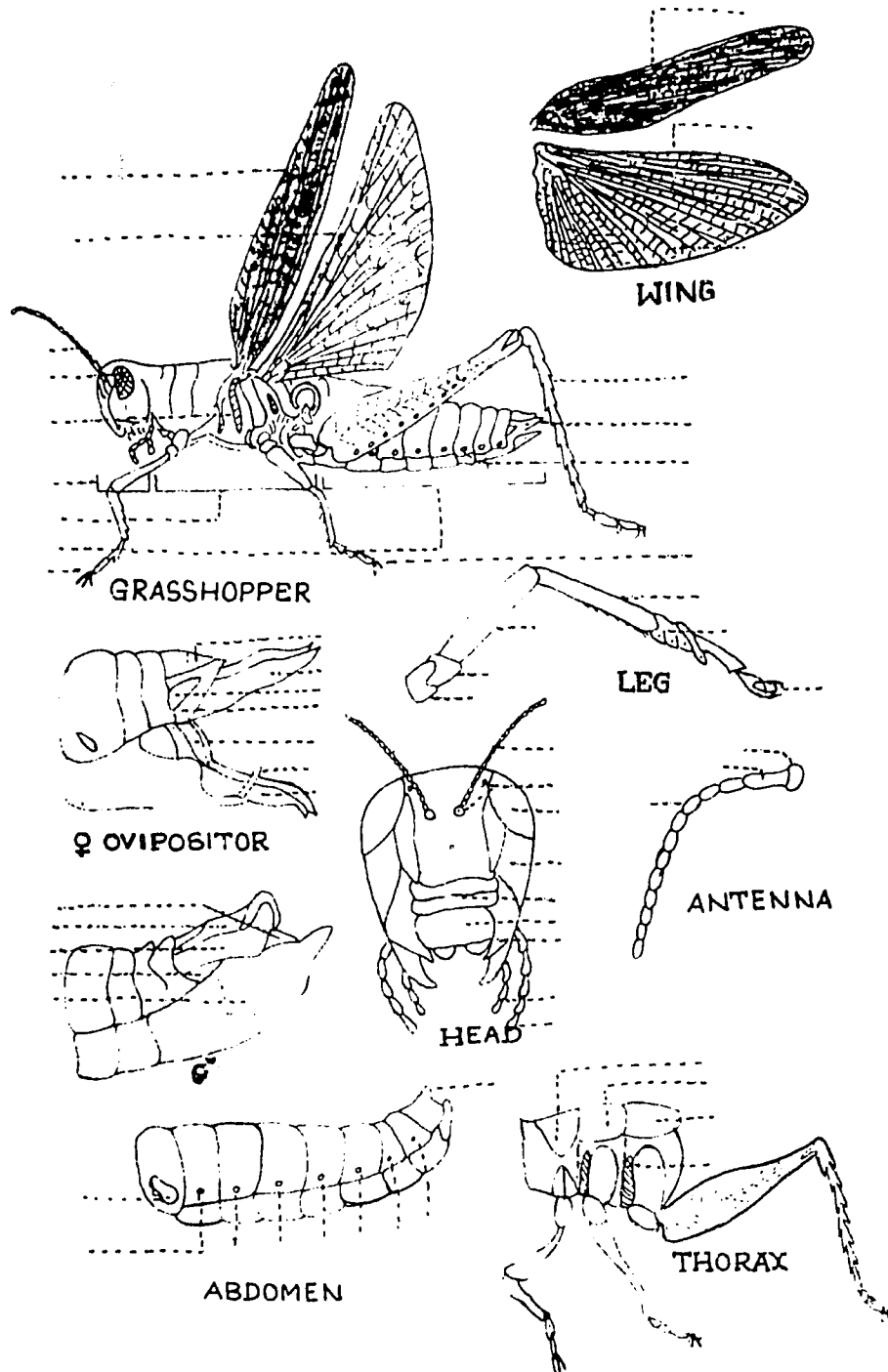


Fig.5. EXTERNAL MORPHOLOGY OF A GRASSHOPPER

LAB 3: EXTERNAL MORPHOLOGY OF AN INSECT (GRASSHOPPER)

OBJECTIVE:

It is necessary to study the external morphology of insects in order to know their body structures, functions and classify them on the basis of their morphological characters.

MATERIALS:

1. Freshly killed grasshopper
2. Dissecting microscope
3. Forceps
4. Needles

METHODS: (Refer page 52 for details)

1. Take a grasshopper and identify its three body regions - head, thorax and abdomen.
2. Study and identify various appendages on head thorax and abdominal regions.
3. Separate various parts such as antennae, legs, wings and identify their different parts.

PROBLEMS:

1. Label various structures (Fig. 5).
2. What are the appendages of head ? Write their distinguishing characteristics.

3. How do you differentiate a male grasshopper from a female?

LAB 4: INSECT MOUTH PARTS AND THEIR MODIFICATIONS

OBJECTIVE:

The mouth parts undergo various modifications on the basis of their feeding habits. There is a definite correlation between the type of mouth parts and the damage they do to the crops. This study helps to recommend appropriate control measures.

MATERIALS:

1. Insect specimens with different mouth types
2. Permanent slides
3. Forceps
4. Camel hair brush
5. Needles
6. Dissecting microscope
7. Glass slides.

METHODS:

A. Biting & chewing type:

1. Take a grasshopper or cockroach and separate head from thorax.
2. Keep head between two slides and press gently.
3. Remove the appendages and arrange them on slide (Fig. 6).
4. Observe under a microscope.

B. Piercing and sucking type:

1. Take a red cotton bug.
2. Separate the head and place it on a slide.
3. Separate and arrange stylets on the slide (Fig. 7).
4. Observe its various parts under microscope. For comparison, take a mosquito and complete the process same as above, observe mosquito mouth parts and compare them with that of red cotton bug.

C. Chewing and lapping type:

1. Take a honeybee, remove head from the thorax, and gently press it between two slides.
2. Observe the parts and identify them.

D. Siphonging type:

1. Take a butterfly or moth, separate head from thorax, press between two slides and observe under microscope.

E. Sponging type:

1. Take a housefly, separate head from thorax, and observe under microscope.

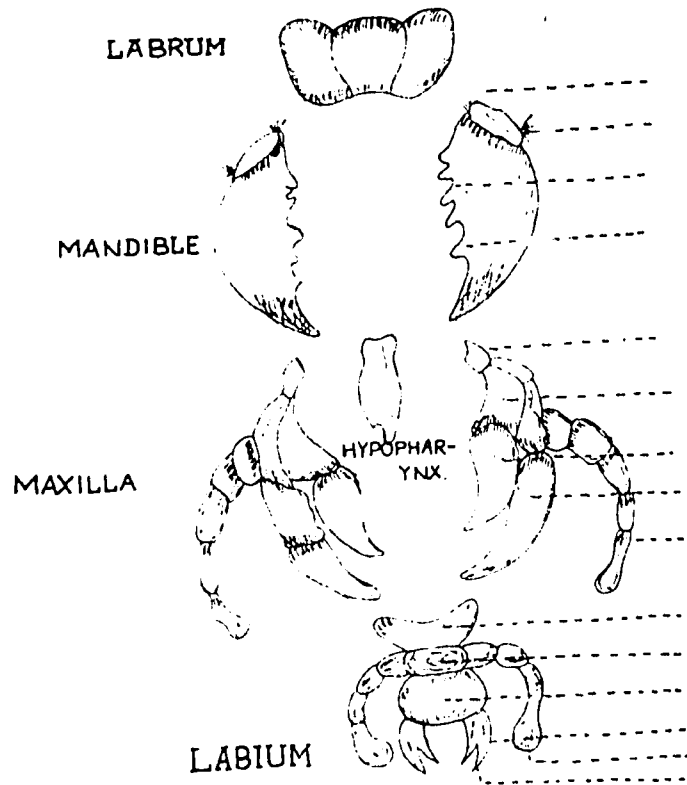


Fig.6. MOUTH PARTS OF GRASSHOPPER

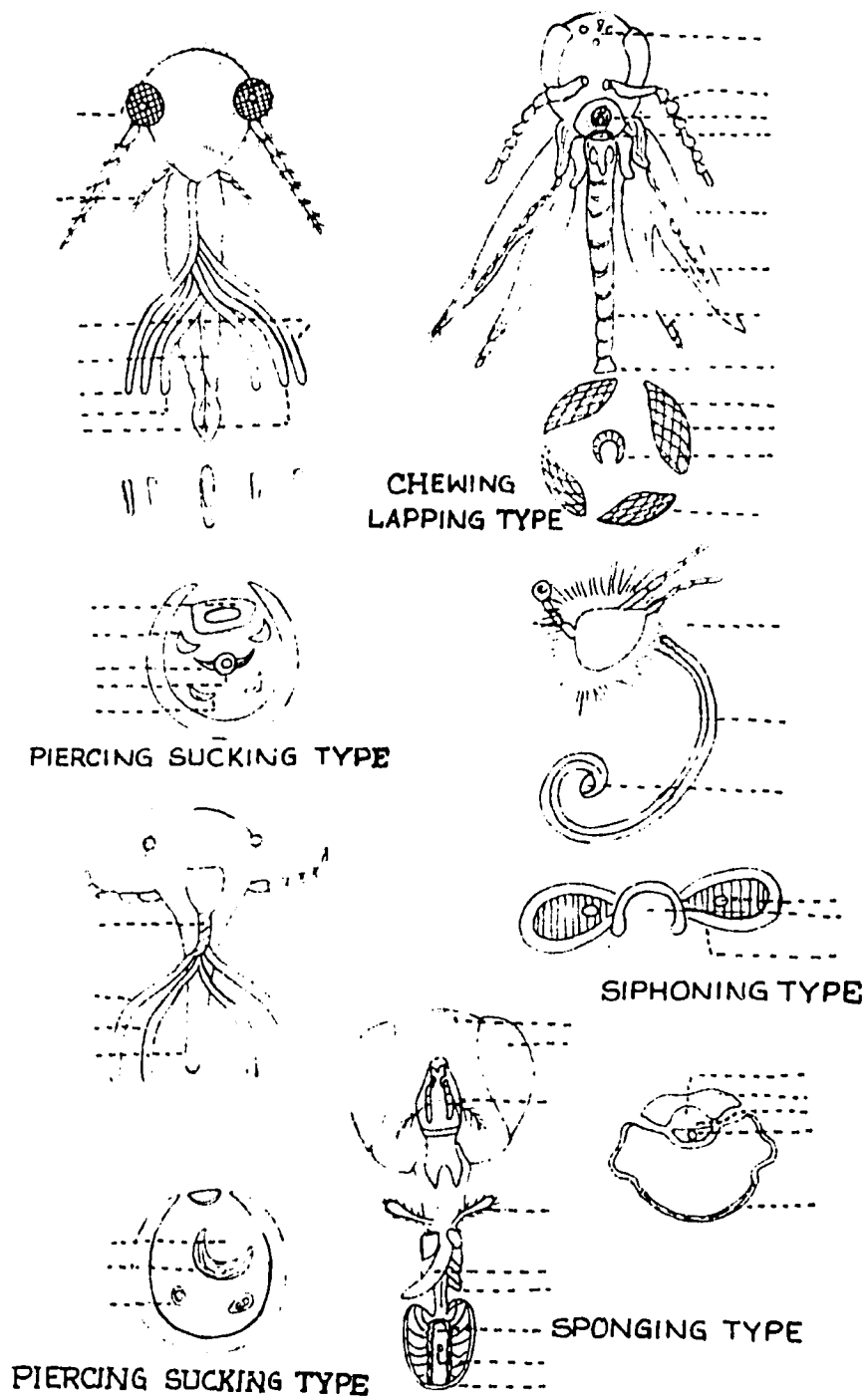


Fig. 7. MOUTH PARTS AND THEIR MODIFICATIONS

Problems:

1. Label the various types of mouth parts (Fig.6 and Fig.7).
2. List two types of mouth parts of insects damaging crops and describe their feeding mechanisms.
3. Which mouth type is fit for feeding on solid and liquid food ? Give an example.
4. How will this knowledge help you to select an appropriate pest control measure?

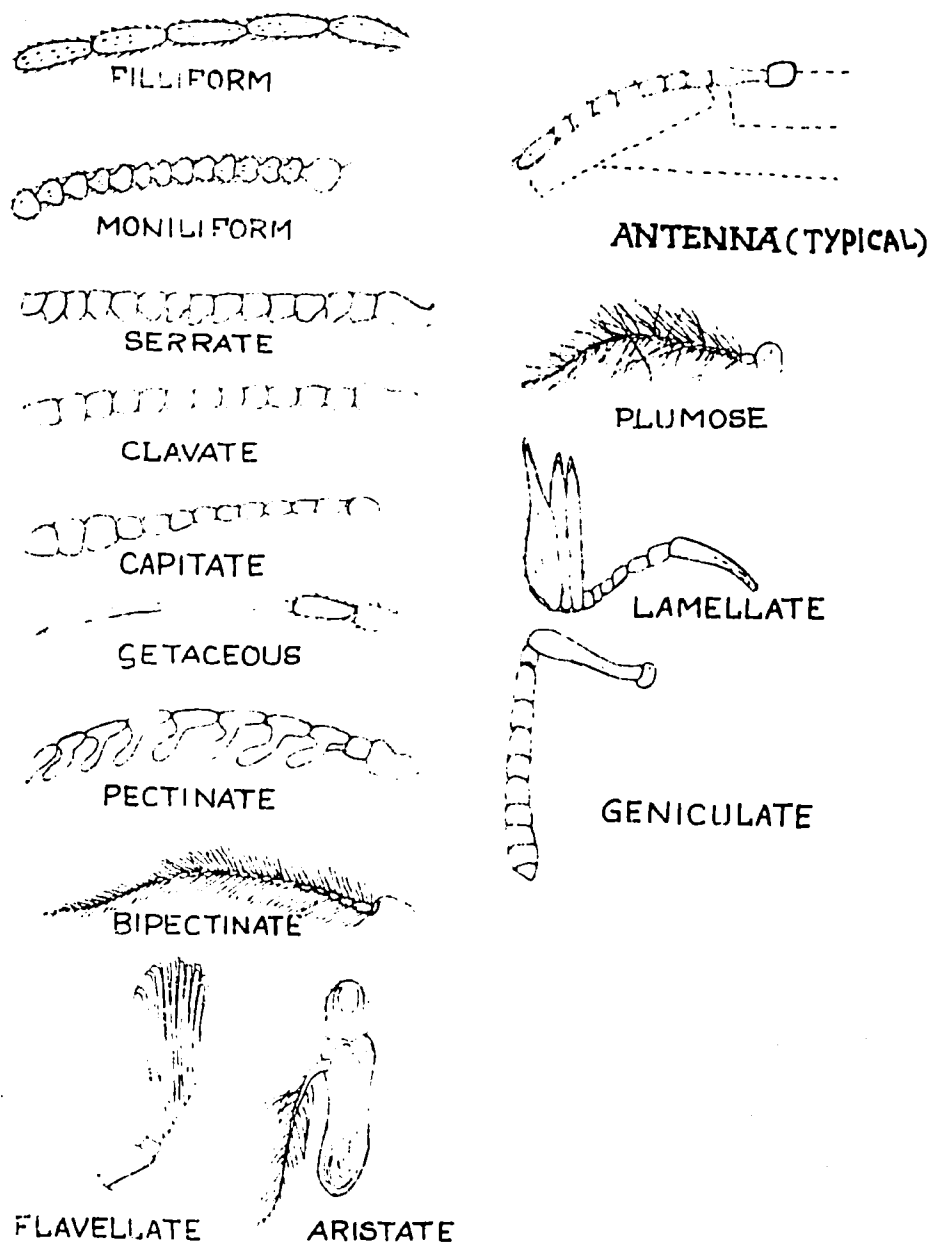


Fig. 8. ANTENNAE AND THEIR MODIFICATIONS

LAB 5: ANTENNAE AND THEIR MODIFICATIONS

OBJECTIVES:

Antennae are the sensory organs of an insect. Various types of modifications have been observed in different insects. Study of these modifications is helpful in distinguishing their characteristics which help in classification.

MATERIALS:

1. Insect specimens with different types of antennae
2. Permanent slides
3. Dissecting microscope
4. Forceps
5. Pins
6. Glass slides.

METHODS:

1. Take an insect, remove its antennae from the base and observe the various parts under the microscope.
2. Separate antennae from other insects and compare them with the permanent slides.

PROBLEMS:

1. What are the different parts of an antenna?
2. Distinguish between a clavate and capitate type of antennae.
3. What types of antennae are found in following insects?

a. Click beetle	d. Honey bee
b. Mosquito	e. Housefly
c. Silkworm	f. Termite

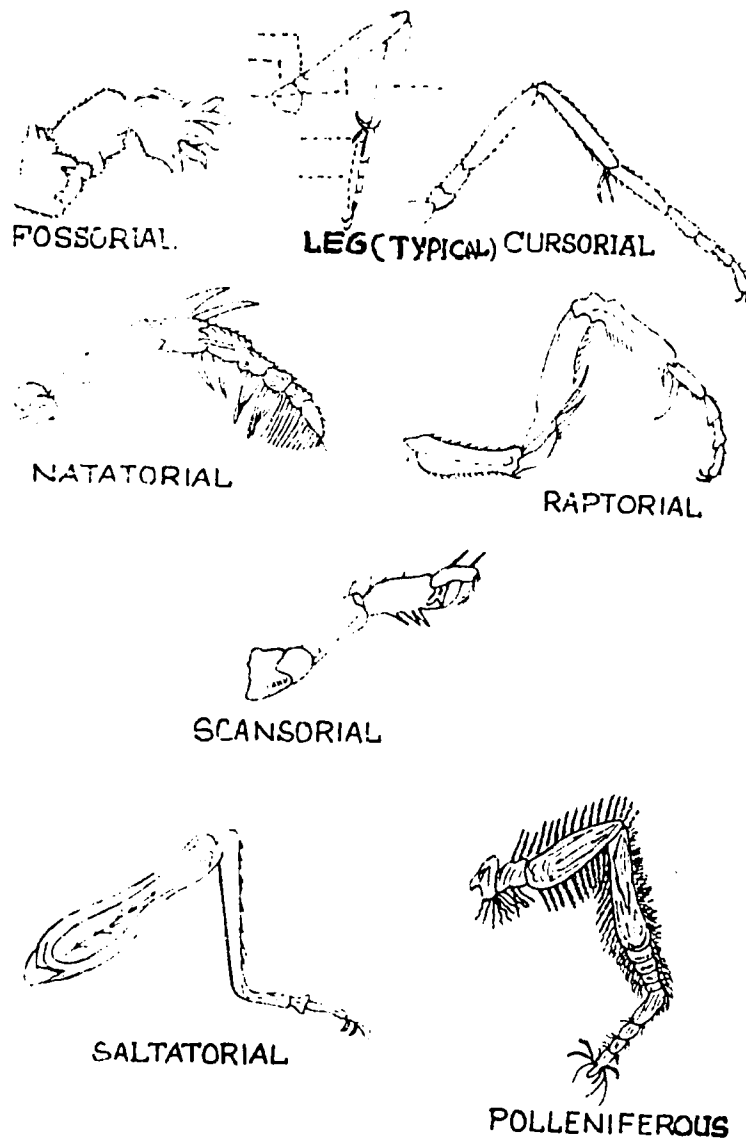


Fig. 9. LEGS AND THEIR MODIFICATIONS

LAB 6: LEGS AND THEIR MODIFICATIONS

OBJECTIVE:

Insect legs primarily function as locomotive organs. However, various modifications have been observed according to the functions they perform. This study is informative to understand various activities associated with legs.

MATERIALS:

1. Insect specimens representing various types of legs
2. Permanent slides of various types of legs
3. Pins
4. Forceps
5. Dissecting microscope
6. Glass slides

METHODS:

1. Take a grasshopper or cockroach, remove its legs from pleural areas and observe the various parts of the legs.
2. Similarly, separate legs of other insects and compare them with permanent slides.

PROBLEMS:

1. Give examples of various leg types (Fig. 9).
2. What type of legs does a honey bee have? What are the various specialized parts?
3. Distinguish between the followings:
 - a. Saltatorial and cursorial type of legs
 - b. Fossorial and raptorial legs

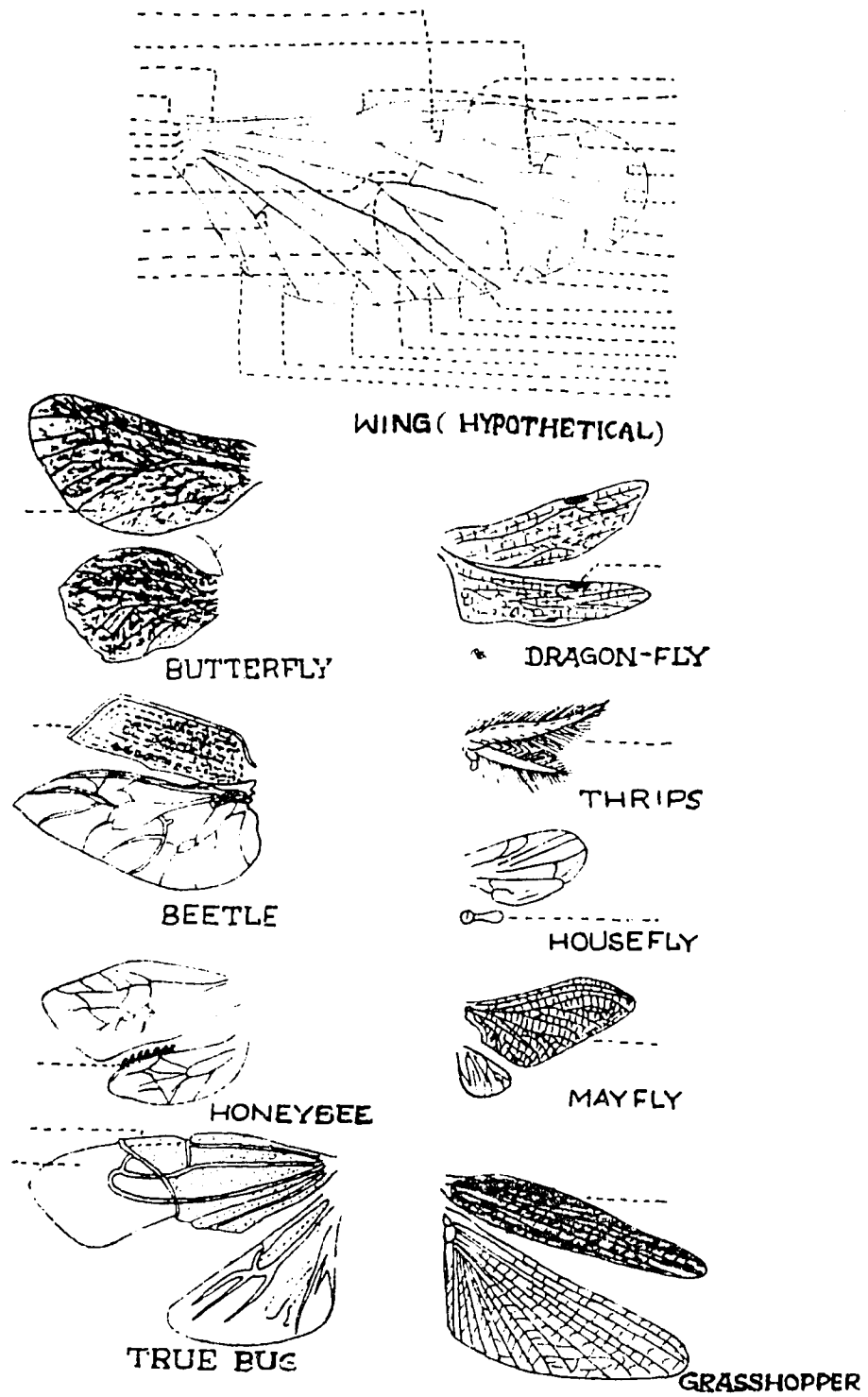


FIG. 10. WINGS AND THEIR MODIFICATIONS

LAB 7:WINGS AND THEIR MODIFICATIONS

OBJECTIVES:

Wings are flight organs of an insect. There are various modifications depending upon the habits and habitats of the insect. The wing structure and venation are important diagnostic characters for insect classification.

MATERIALS:

1. Insect specimens with different types of wings
2. Permanent slides of various wing types
3. Forceps
4. Needles
5. Microscope
6. Glass slides

METHODS:

1. Take a wing of housefly and observe the venation.
2. Separate other types of wings and observe and compare them with permanent slides and sample specimens.

PROBLEMS:

1. Label a typical housefly wing (Fig 10).
2. Label other wing types.
3. Name insects having following types of wings:
 - a. Fringed
 - b. Scaly
 - c. Tegmina
 - d. Halteres
4. Distinguish between the followings:
 - a. Jugum and Frenulum
 - b. Elytra and Hemelytra

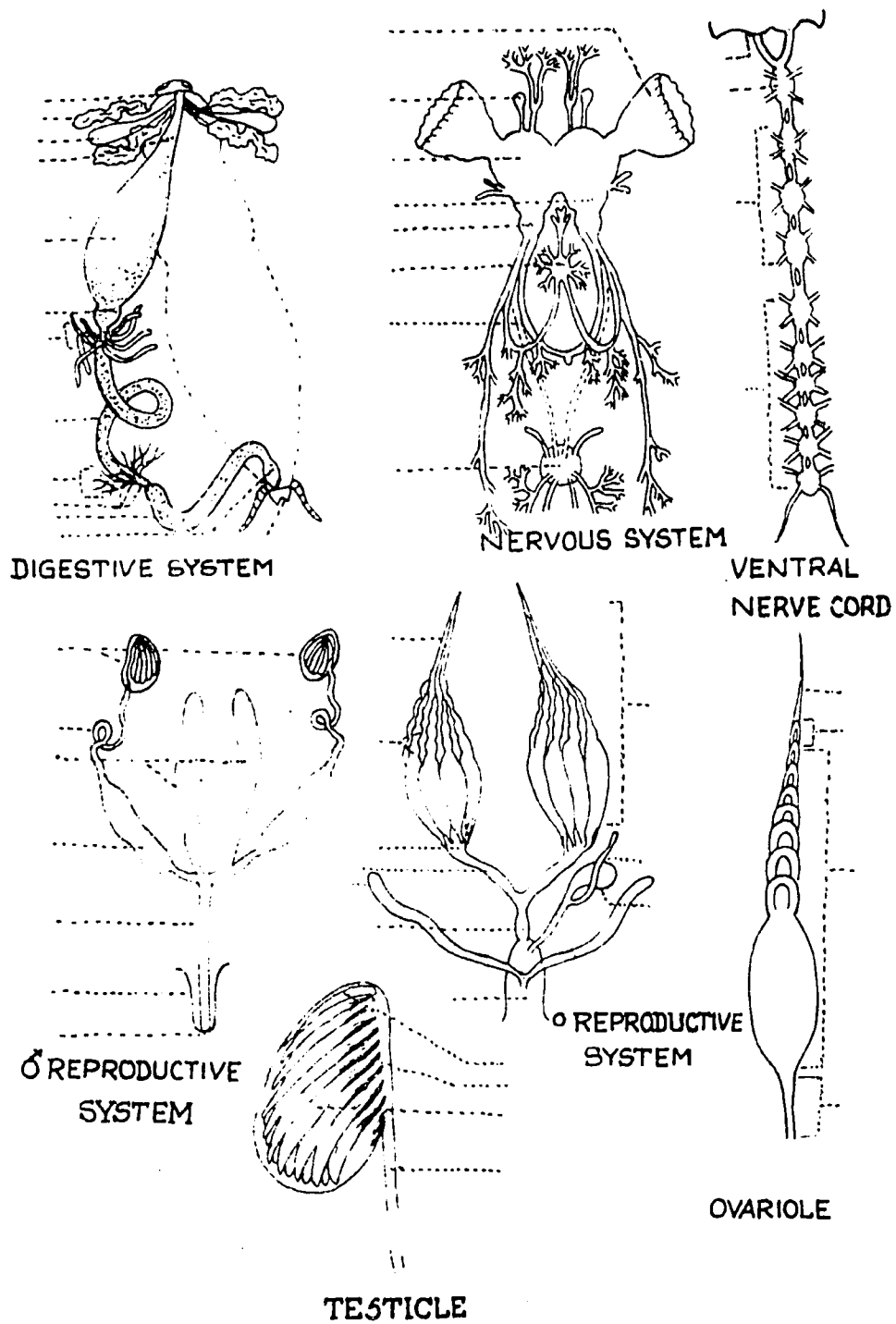


Fig.11. INTERNAL ANATOMY – DIGESTIVE, NERVOUS AND REPRODUCTIVE SYSTEMS

LAB 8: INTERNAL ANATOMY OF AN INSECT

(a) Digestive, Nervous and Reproductive Systems:

OBJECTIVE:

Study of these systems is necessary to relate the physiological processes of internal organs with insect behavior, development, their survival, and the means to be taken for their control.

MATERIALS:

1. Freshly killed specimen (cockroach)
2. Dissecting tray
3. A pair of scissors
4. Pins
5. Sample dissection

METHODS:

1. Take a freshly killed cockroach.
2. Cut off its legs and wings.
3. Place the cockroach in dissecting tray and pin on its head, cover with water.
4. Give a dorsal cut from the posterior region towards the head with the help of scissors.
5. Remove dorsal body wall with the help of a pin and forceps.
6. Pin the lateral margins placing them at an angle of 45 degree. Remove all fatty tissues, air sacs, tracheae and muscles.
7. Bring alimentary canal apart and observe its various parts (Fig. 11).
8. Observe the ventral nerve cord and thoracic ganglia.
9. To observe reproductive parts, remove alimentary canal separating it from rectum, pin the rectum stretching posteriorly.
10. Separate ovaries, testes and observe their various parts (Fig. 11).
11. Compare different systems and their parts with sample dissection.

PROBLEMS:

1. Label various parts of digestive, nervous, and reproductive system (Fig 11).
2. What is malpighian tubule? Write its function.
3. How will you distinguish between a male and a female reproductive system?

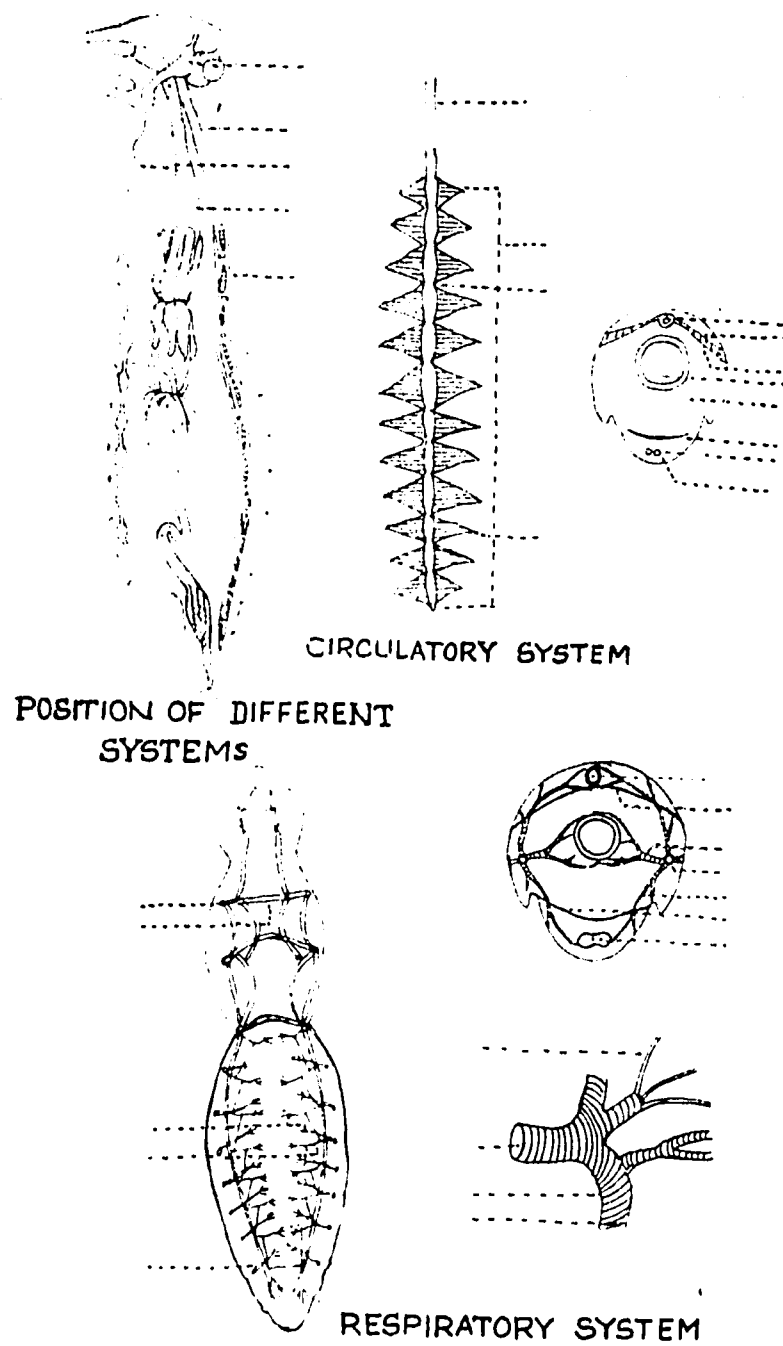


Fig. 12. INTERNAL ANATOMY- CIRCULATORY AND RESPIRATORY SYSTEMS.

(b) Circulatory and Respiratory Systems:

OBJECTIVE:

Study of these systems helps to identify the various parts, their position, and functioning mechanisms.

MATERIALS:

1. Freshly killed grasshopper or cockroach
2. Dissecting tray
3. Pins
4. Forceps
5. Sample dissection
6. A sharp blade

METHODS:

1. Take a freshly killed grasshopper or cockroach.
2. Remove its legs and wings.
3. Place the specimen in tray covering with water.
4. Make a laterodorsal cut on both sides with the help of a sharp blade.
5. Remove tergum carefully and observe heart and alary muscles.
6. On both sides observe the silvery white tracheae running parallel to heart.
7. Remove digestive tract and observe visceral longitudinal tracheal trunk and spiracular tracheae.
8. Also observe ventral pair of longitudinal trachea.

PROBLEMS:

1. Identify the positions of circulatory, digestive and nervous systems in an insect body and label them (Fig 12).
2. What are alary muscles? How do they function in blood circulation?
3. How exchange of gases does take place in an insect?

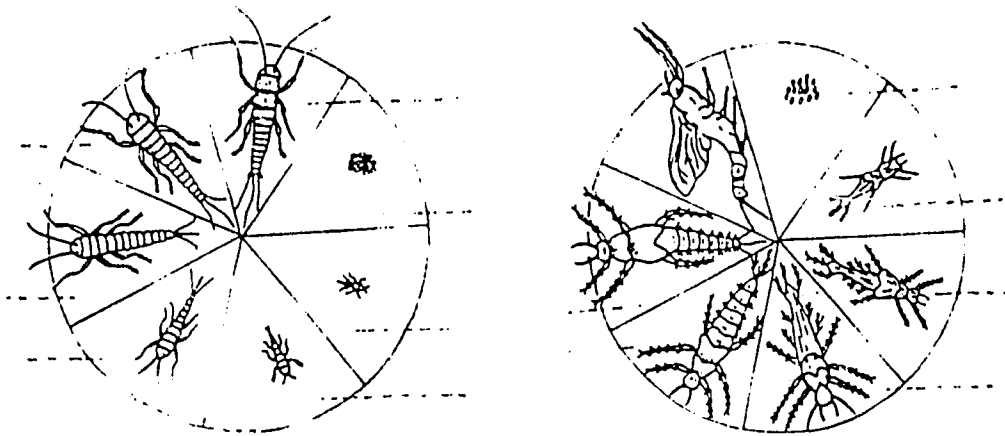


Fig.13. INSECT METAMORPHOSIS
(AMETABOLA & HEMIMETABOLA)

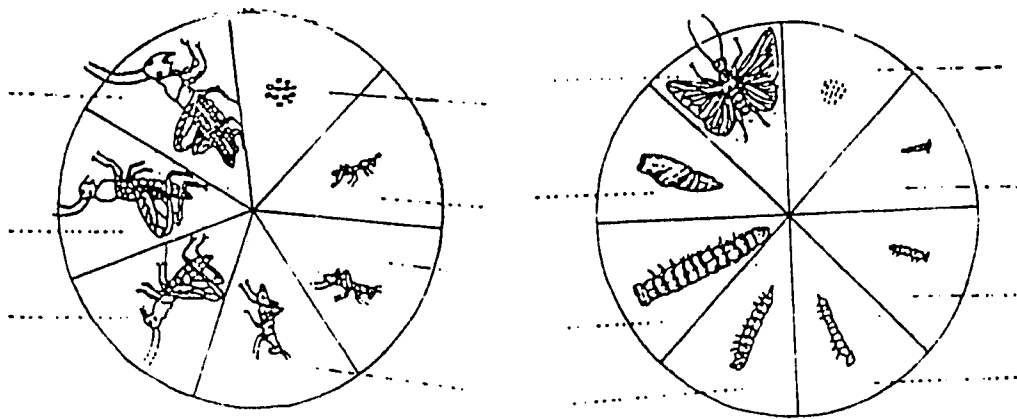


Fig.14. INSECT METAMORPHOSIS
(PAUROMETABOLA & HOLOMETABOLA)

LAB 9: INSECT METAMORPHOSIS

OBJECTIVE:

Study of different stages in development of an insect, helps in timing the control operations as also forecasting the insect epidemics.

MATERIALS:

1. Preserved specimens including various stages of :
 - a. Silverfish
 - b. Grasshopper
 - c. Mayfly
 - d. Butterfly

METHODS:

1. Observe the different growth stages of those insects in the laboratory (Fig. 13 and 14).
2. Note the external characteristics of adults and immatures (young, nymph, naiads larvae and pupae).

PROBLEMS:

1. Label the various stages (Fig. 13,14).
2. How does a nymph differ from its adult?
3. Differentiate between the gradual and incomplete metamorphosis.
4. Name the various stages of development in a moth, and write their characteristics.

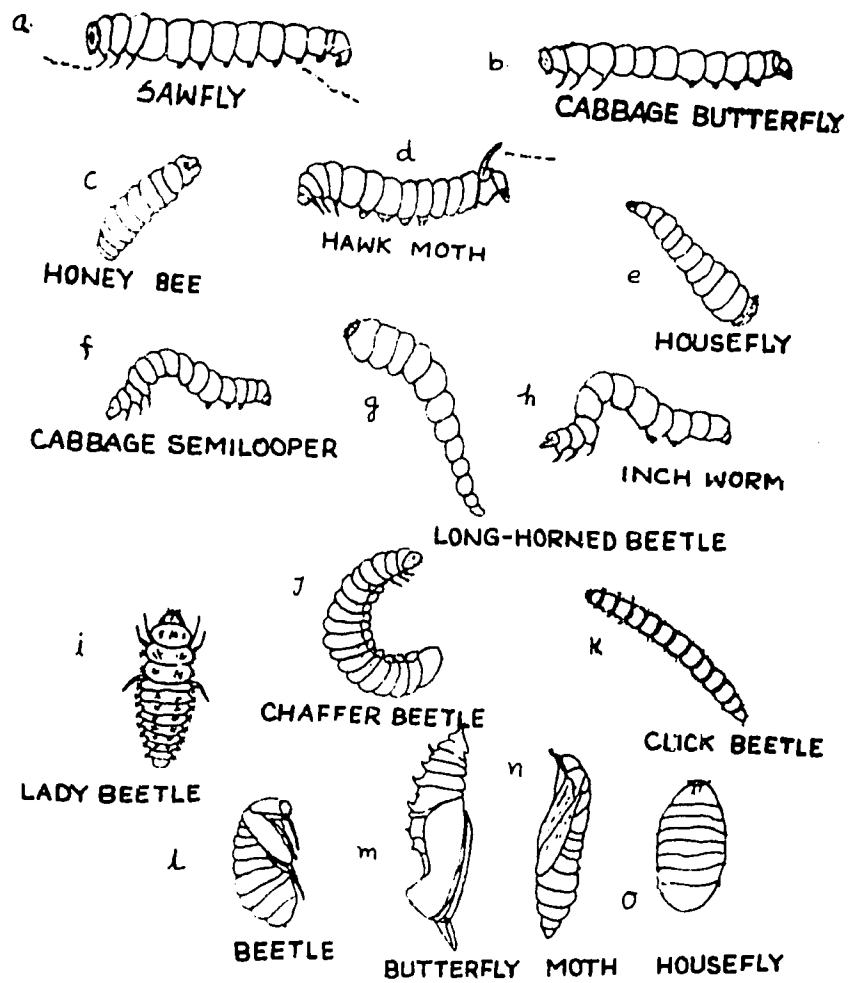


Fig.15. TYPES OF LARVAE AND PUPAE

(a-k: larvae; l-o: pupae)

LAB 10: TYPES OF LARVAE AND PUPAE

OBJECTIVE:

This study helps us to identify the various larval and pupal forms which will help to recognize their presence and the necessary steps to be taken for their control.

MATERIALS:

1. Various forms of larval and pupal specimens.
2. Dissecting microscope.

METHODS:

1. Observe the external characteristics of larvae such as head, thoracic legs and prolegs (abdominal legs) with the help of dissecting microscope.
2. For pupae, observe the pupal shape and body appendages -free or glued to the main body.

PROBLEMS:

1. Label the various larval and pupal forms (Fig. 15).
2. What are larvae and pupae?

3. Differentiate between the followings:
 - a. Legs and prolegs

b. Maggots and grubs

c. Loopers and semiloopers

d. Obtect and exarate pupae

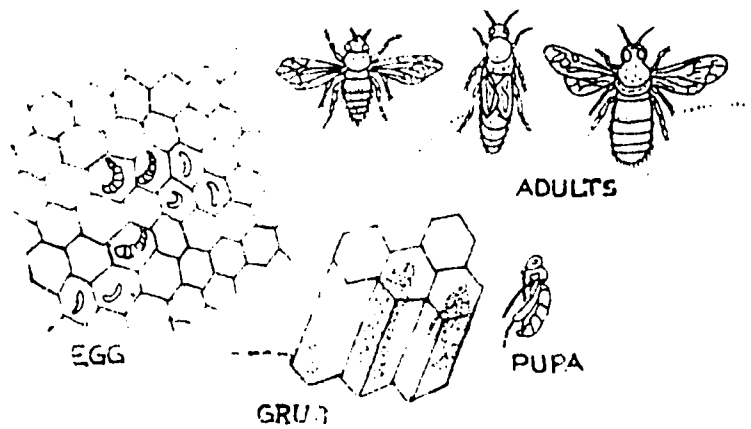


Fig.16. LIFE CYCLE OF HONEY BEE

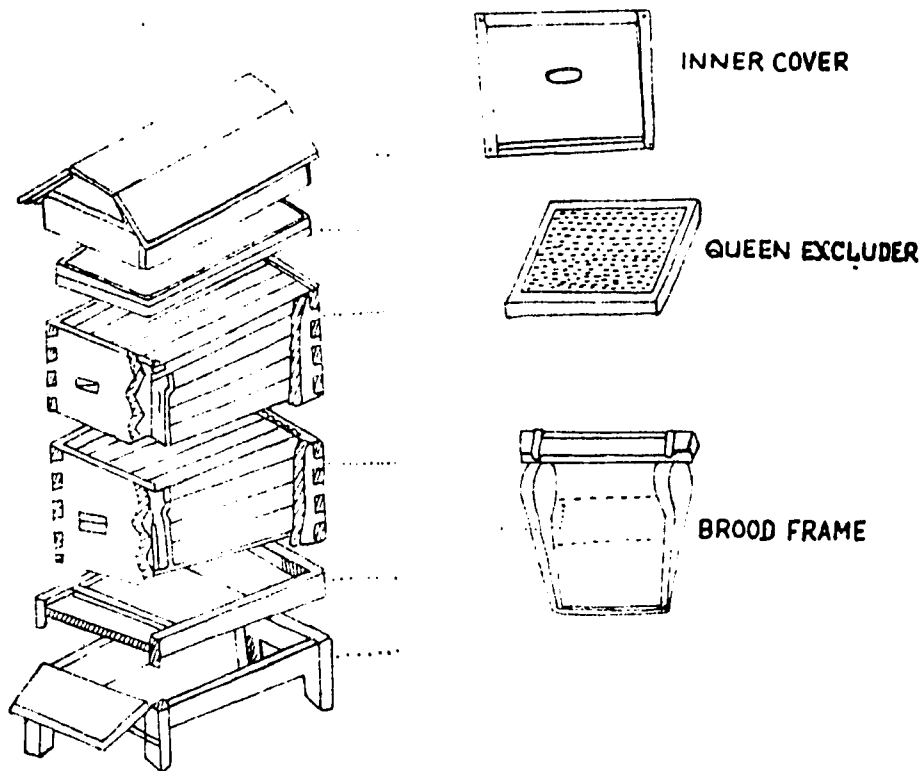


Fig.17 PARTS OF A BEE HIVE

LAB 11: LIFE CYCLE OF HONEY BEE
(Apis indica Fabricius)

OBJECTIVE:

This study is very much informative to understand their social, behavioral, communication and developmental aspects.

MATERIALS:

1. Various growth stages of a honey bee including queen, drone and worker.
2. Bee comb with queen, worker and drone cells.

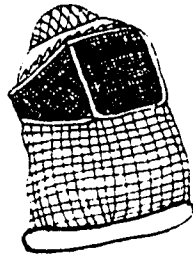
METHODS:

1. Observe different developmental stages (egg to adult) and caste (queen, drone and worker) on the basis of their body characteristics.
3. Have a close look on queen, drone and worker cells and their arrangement in a comb.

PROBLEMS:

1. Label the different caste of honey bee (Fig. 16).
2. How would you recognize workers, drones and queen? Give their characteristics.

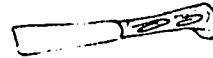
3. How long does it take to produce a queen? What kind of food is given to a designated queen grub?



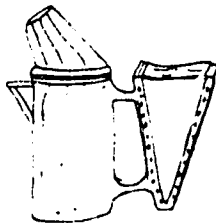
VEIL



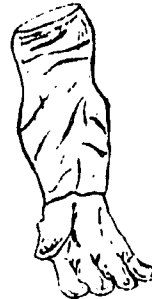
BRUSH



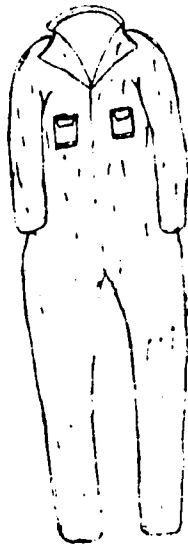
HIVE TOOL



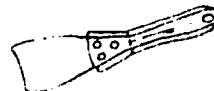
BEE SMOKER



GLOVE



COVER ALL



HIVE SCRAPER

Fig.18 BEEKEEPING EQUIPMENT

LAB 12: MODERN BEE HIVE AND ITS PARTS

OBJECTIVE:

Bee hive and beekeeping equipment are basic tools for the beekeepers. This study is necessary to familiarize with modern bee hive, its parts, functions, and beekeeping equipments for better management and care of a bee colony.

MATERIALS:

1. A modern bee hive (Langstroth's hive)
2. Bee keeping equipment

METHODS:

1. Open the sample bee hive removing its parts one by one and then arrange them back in the same position.
2. Observe the various parts of a bee hive.
3. Visit an apiary, observe demonstrator using various bee equipment, (Fig. 18) and handling a bee colony.
4. Observe a queen, drones and workers inside the hive and be familiar with the brood cells, honey and pollen storage in a comb.

PROBLEMS:

1. Label the various parts of a bee hive (Fig. 17).
2. What is super? How does it differ from a brood chamber?

3. What do you mean by the followings?

a. Queen gate:

b. Queen excluder:

c. Bee space:

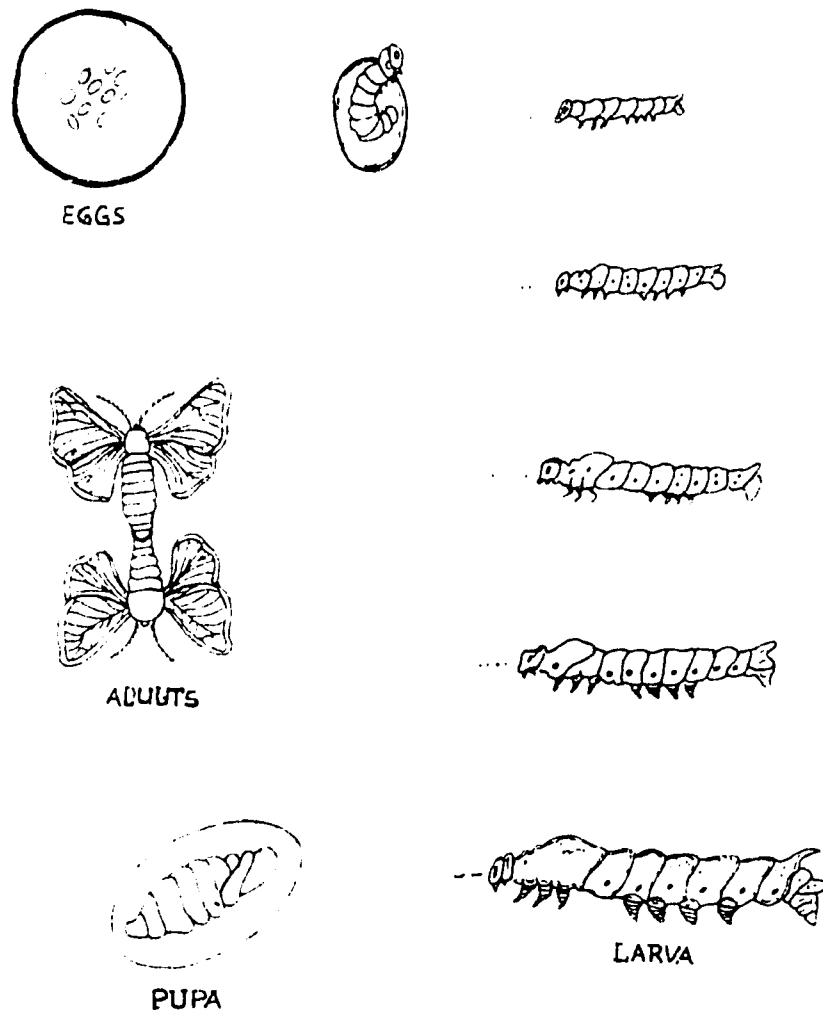


Fig.19 LIFE CYCLE OF MULBERRY SILKWORM

LAB 13: LIFE CYCLE OF MULBERRY SILKWORM
(Bombyx mori Linnaeus)

OBJECTIVE:

This study is aimed to identify the different stages of mulberry silkworm which helps for their proper care during different developmental stages and obtain better cocoon production.

MATERIALS:

1. Preserved various stages of mulberry silkworm
2. Cocoons

METHODS:

1. Observe the various developmental stages of a mulberry silkworm: eggs, larvae, pupae (cocoons) and adults .
2. Visit a silkworm rearing house and be familiar with rearing condition, different larval stages, their feeding, moulting and cocoon harvest.

PROBLEMS:

1. Label the larval developmental stages of a mulberry silkworm (Fig. 19).
2. Distinguish between a male and a female silkworm adult.

3. What do you mean by larval moulting?

4. What is cocoon? How does a silkworm larva produce cocoon?

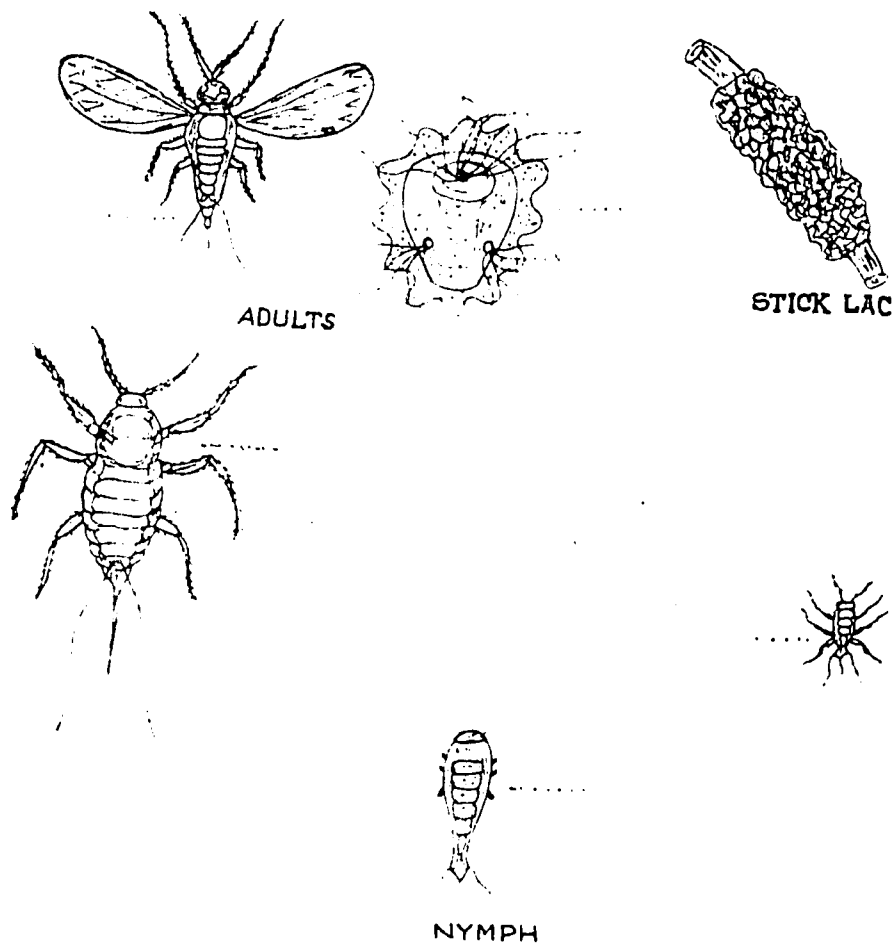


Fig.20. LIFE CYCLE OF LAC INSECT

LAB 14: LIFE CYCLE OF LAC INSECT
(Kerria lacca Kerr.)

OBJECTIVE:

Knowledge of lac insect and its different growth stages are essential for the proper management to ensure a good lac production.

MATERIALS:

1. Different growth stages of a lac insect
2. Stick lac

METHOD:

1. Observe different growth stages of a lac insect.
2. Have a close look on stick lac and be familiar with it.

PROBLEMS:

1. Label immatures and adults (Fig. 20).
2. Distinguish between a male and a female lac insect.

3. What is a stick lac? How is it formed?

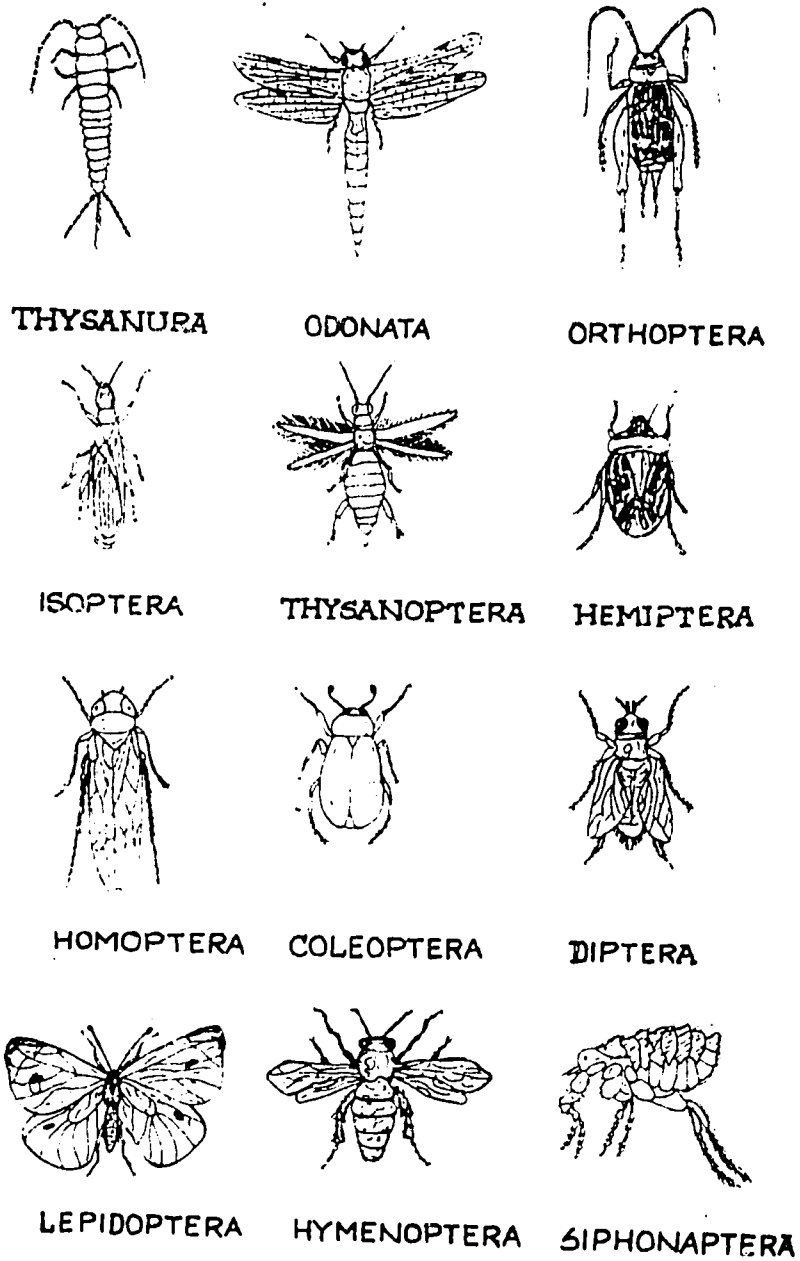


Fig. 21. INSECT CLASSIFICATION - ORDERS

LAB 15: CLASSIFICATION OF INSECTS

OBJECTIVE:

This study is very useful to apply the previous morphological characteristics for identifying insects and use of taxonomic key to classify them into their respective orders and families.

MATERIALS:

1. Specimens representing different orders
2. Dissecting microscope
3. Taxonomic key to the order of insects
4. Sample specimens

METHODS:

1. Use the taxonomic key provided to you and follow identifying characteristics observing insects under dissecting microscope.
2. Note the external characteristics of an insect and conform by comparing with the sample specimen.

PROBLEMS:

1. Give one or two examples of insects belonging to each order (Fig. 21).
3. Name various types of mouth parts and wing structures observed in different orders.
4. Write down one or two important characteristics of different families (Fig. 22 to 28).

5. Distinguish between followings:

a. Hemiptera and Homoptera

b. Diptera and Hymenoptera

c. Butterfly and moth

d. Beetle and weevil

e. Treehopper and planthopper

f. Mole cricket and field cricket

g. Red cotton bug and gundhi bug

6. How would you identify the followings:

a. Housefly

b. Honey bee

c. Fruitfly

d. Mosquito

e. Ant

f. Skipper

g. Stink bug

LAB 16: DILUTION OF PESTICIDES

OBJECTIVE:

It is essential to develop skill of pesticide calculation at a desired concentration for the economic use of pesticide and saving crops from pesticide injury.

MATERIALS:

1. Pesticide in liquid or solid form
2. Diluent (water, sand or saw dust)

METHODS:

1. Read the instructions on the concentration of pesticide to be used for spray or dust.
2. Read the pesticide label for concentration available in the market.
3. Calculate the amount required by using formula (page 86).

PROBLEMS:

1. What is pesticide? What are the different forms available in the market?
2. 200 ml of methyl-parathion (Metacid 50 EC) is added to 100 litres of water in a spray tank. What is the concentration of spray?
3. Calculate the amount of carbaryl (Sevin 50 WP) to prepare 1000 litres of spray solution of 0.1% concentration.
4. How many kg of BHC (40%) dust will be required to prepare 500 kg of dust containing 5% concentration?

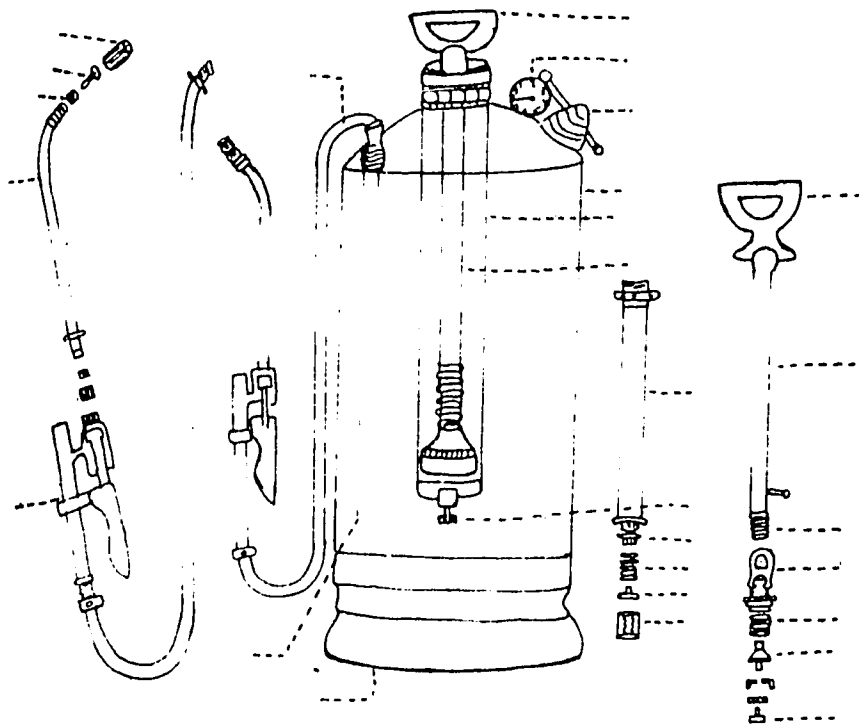


Fig.22.PARTS OF A HAND COMPRESSION SPRAYER

LAB 17: PESTICIDE APPLIANCES

OBJECTIVE:

It is important to have knowledge of pesticide appliances, their various parts and functions. This helps to identify the problem of appliances, their proper use, care and maintenance.

MATERIALS:

1. Sprayers
2. Dusters
3. Soil injectors
4. Flame thrower
5. Seed dressing drum

METHODS:

1. Observe the various types of pesticide appliances (Fig. 30 and 31).
2. Learn to separate and assemble the various parts of a hand compression sprayer.

PROBLEMS:

1. Label the various parts of a hand compression sprayer (Fig. 22).
2. What are sprayers and dusters? How does a sprayer differ from a duster?
3. What are the precautions to be taken while using a pesticides appliance?

Calibration of a Sprayer:

OBJECTIVE:

This study will help to develop skill in spraying and find out the exact amount of spray at desired rate per unit area.

MATERIALS:

1. Sprayer (in good working condition)
2. Stop watch
3. Measuring tape
4. Water (spraying solution)

METHODS:

1. Fill a tank with water, provide required pressure and record the discharge in ml/min.
2. Spray in the field, note the amount sprayed (ml), and the distance travelled (m) with width (m).
3. Calculate the spraying liquid required (lit/ha), by formula (page 93).

PROBLEMS:

1. A sprayer having a nozzle discharge of 650 ml/min can cover 40 m long distance with 1.5 m swath width. Calculate the amount of spray and time required for 5 hectares of land.
2. A sprayer having a nozzle discharge of 600 ml/min can cover 50 m long distance covering a width of 1 meter. Calculate the amount of spray and number of runs required per hectare.

STUDY GUIDE

1. STUDY OF A MICROSCOPE

A Microscope is an important instrument used in biological sciences. To-day there is a vast range of microscopes available including the electronic microscope, to suit each and every requirement of the scientists.

The main function of a microscope is to enlarge the image of an object with the help of lenses. This makes easier to study the morphological, anatomical, histological and other characteristics of an object. It also facilitates measuring sizes of smaller objects.

The common types of microscopes used by students in the field of entomology are the dissecting and binocular microscopes.

A. **Parts of a microscope:** A binocular microscope has following parts (fig 1):

1. Eye piece
2. Eye tube
3. Focusing knob
4. Stage
5. Clips
6. Mirror
7. Base (stand)
8. Magnifying knob
9. Power body
10. Locking screw.

B. **Care and handling of a microscope:** Proper care and handling is necessary to keep the microscope in sound working condition. In addition, it also increases life expectancy of a microscope. Pay attention to the following points:

1. Carry the microscope in an upright position, by putting one hand on the handle and supporting the base with other hand.
2. Avoid tarring suddenly.
3. Keep microscope free from dirt and dust.
4. Clean lenses with lens paper only.
5. Always use clean glass slides with specimen on it.
6. Reflect the mirror towards the light source.
7. Always start focusing with low power to bring the object in the objective field. Use higher magnifications gradually.
8. Clean the microscope after finishing your work.
9. Store the microscope in a cabinet with a cover over it.

C. **Use of stage and ocular micrometers:** Objects are measured by using ocular and stage micrometers. Calibration is done for each magnification to determine the value of a division of ocular micrometer by measuring it with the known units on the stage micrometer.

1. **Stage micrometer:** This is a glass slide in which one millimeter scale is divided into 100 equal divisions and each division measures 0.01 mm (10 microns).

2. **Ocular micrometer:** This is a small glass disc which can be fitted into an eye piece. It has a scale of one centimeter long, divided into 100 equal parts and each division measures 0.1 mm (100 microns).

3. **Calibration method:**

- i. Place the ocular micrometer into the eye piece and the stage micrometer on the microscopic stage.
- ii. Focus the scale of both micrometers.
- iii. Record the division of ocular micrometer and stage micrometer from the point of one coincidence to the next. Repeat this process several times.
- iv. Take the average of the ocular and stage micrometer readings separately.

4. **Formula for calibration:**

$$I = S/O \times 10 \text{ microns.}$$

where, I = Index of ocular micrometer
 S = Divisions of stage micrometer
 O = Divisions of ocular micrometer

Multiply the length and width of a given object by this index. Keep in mind to use the same magnification for calibration and specimen measurement.

2. INSECT COLLECTION AND PRESERVATION

Insect collection is an art. Some people collect insects as a hobby while others make the collection as their profession. They study the fascinating creatures in detail including their identification, habits and habitat. The scientists who specialize in this field are known as entomologists.

Insect collection is a rewarding hobby. It increases knowledge of insect biology, ecology and their feeding habits. Properly set, pinned, arranged and preserved collection has a great scientific value.

A. Where to find insects?

Insects are found almost everywhere except deep down in the oceans. Periodical visit to the following places and collection will make you a good insect collector.

1. **Plants:** Look under the leaves, flowers and inside dead branches. A large number of insects feed on grasses, various crops, vegetables, fruits and forest trees.
Example: Butterflies, beetles, grasshoppers, whiteflies etc.

2. **Soil:** There are subterranean insects that live in the soil. Some will be found inhabiting compost, mulch and plant debris as well.
Example: Termites, cutworms, wireworms, crickets etc.

3. **House and barn:** Insects live in cracks and crevices under boxes and dark corners (silverfish, house-crickets etc). Storage grains have various coleopterian and a few lepidopterous insects. Livestock also serves as a good host and harbour many lice, flies and mosquitoes.

4. **Light:** At night insects are often seen hovering around lights. Place a trap below a light and collect the insects.
Examples: Noctuid moths.

5. **Water:** Many insects live in ponds and streams. They are known as aquatic insects. Collect them from the surface as well as from the bottom of water.
Examples: Dragonflies, damselflies, water bugs, water beetles.

B. How to prepare a killing jar?

There are different types of insect killing jars. Preparation of two common killing jars are given below:

Ethyl acetate killing jar (Fig. 2):

1. Keep 1.5 to 2.0 cm layer of dry sand or saw dust on the bottom of a jar.
2. Pour over this, 1.0 to 1.5 cm thick layer of wet plaster of paris and set it to dry.
3. Saturate it with ethyl acetate.
4. Label the jar "POISON".
5. Place a filter paper on top of the dry plaster layer and use it for killing insects.
6. Keep the cork or lid tight so that gas does not leak.
7. Recharge after 2-3 days.

2. Cyanide killing jar (Fig. 2):

1. Put approximately 5 - 10 gm of sodium cyanide on the bottom of a wide mouth bottle with a tight cork or lid.
2. Cover the cyanide with 1.5 to 2.0 cm thick layer of saw dust.
3. Pour 1.0 to 1.5 cm layer of plaster of paris over the saw dust.
4. Make small holes on the well set plaster of paris layer.
5. Put a filter paper on the top of the plaster layer.
6. Label the jar "POISON"

Though cyanide jar lasts longer than one with ethyl acetate, it is more hazardous and should be avoided as far as possible.

C. How to pin insects?

Insects are usually pinned on the thorax. Use a pinning block to maintain the proper height of an insect and labels on the pins. Various pinning positions have been given in Fig. No. 3 for major insect orders.

1. **Mesothorax** (in between the two fore wings): For butterflies, moths, mantids, cockroaches, flies, wasps, bees, etc.
2. **Pronotum** (posterior part): For grasshoppers, crickets, tree-hoppers, leaf-hoppers, plant-hoppers, spittle bugs.
3. **Scutellum**: For all true bugs, pin slightly towards the right of the middle line.
4. **Elytron** (right fore wing): For beetles and weevils. Pin on the right elytron slightly right of the straight line.

D. How to set insects?

Setting is necessary to get the specimen arranged in a neat and attractive fashion as in case of butterflies, moths, skippers, dragonflies and damselflies.

1. Pin insect in the groove of the spreading board.
2. Bring the fore- and hindwings forward (Fig. 4) and spread a small stripe of paper over them. See that the inner margin of forewing makes a right angle with long axis of the body.
3. Pin the paper on four corners.
4. Keep antennae and abdomen in proper position providing supports with pins.
5. Small insects are pinned with a minute (15 mm long, thin fine pin) and mounted on a piece of card, and the card is itself mounted on a regular pin.
6. Insects too small to pin are mounted on a triangular piece of card (3-4 mm base, 8-10 mm long). The insects are glued properly near the tip of the card, and the card is set on a regular pin.

E. How to preserve insects?

Adult insects after pinning and setting, are dried and preserved in collection boxes. A few naphthalene balls are kept inside the boxes as repellent. Silica gel is also used to absorb moisture inside the boxes thereby preventing fungal growth. One should check the specimen regularly and these can also be dried in the sun periodically.

Immatures are preserved in various types of solutions. Kill them in hot water (put them for 3-4 minutes in boiling water) and transfer in a small vial containing either 70-75% solution of alcohol or 8-10% formalin solution.

3. EXTERNAL MORPHOLOGY OF AN INSECT (GRASSHOPPER)

Insects are small animals. Adult insects possess three distinct body regions: head, thorax and abdomen; a pair of antennae, three pairs of jointed-legs, usually a pair of compound eyes and two pairs of wings, sometimes one pair and rarely none.

External morphological study of insects is essential in order to understand the body structures, their positions, functions and coordination with other organs of the insect body. Insect classification (systematics) is mainly based on the external morphology like wing structures, types of mouth parts and metamorphosis.

Insect body regions:

A. Head - The first body region consisting of following parts:

1. **Compound eyes:** Two large shiny, oval eyes situated laterally one on either side of the head.
2. **Ocelli:** Simple eyes located a little dorsomedially to compound eyes.
3. **Antennae:** A pair of long segmented, thread like structures, articulated to the head in front of compound eyes.
4. **Mouth:** Located on the ventral part of head; bearing many appendages such as labrum, mandibles, maxillae and labium.

B. Thorax - Second body region consisting of three segments-pro-, meso- and metathorax.

1. **Prothorax:** It bears a pair of forelegs.
2. **Mesothorax:** This bears a pair of middle legs, forewings and mesothoracic spiracles.
3. **Metathorax:** It bears a pair of hindlegs, hindwings and metathoracic spiracles.

C. Abdomen - Third and largest region of insect body. It is usually 11 segmented. Sex is easily distinguished by abdominal appendages like external genitalia. Females have comparatively larger abdomen with hook like projections at the end (Fig. 5). The terminal portion of the male is hood-shaped. Each abdominal segment (I to VIII) has a pair of spiracles located on the lateral sides.

4. MOUTH PARTS AND THEIR MODIFICATIONS

Mouth parts and their appendages form very important organs of an insect head. They are used in procurement and ingestion of food. Most insects feed on plants. We are mostly concerned with those insects that are pests on agricultural crops. Nature of crop damage is related to the type of mouth parts of an insect. Thus, study of mouth parts is one of the important aspects which helps to identify the crop damage and the steps to be taken to prevent them.

In general, insects have the following mouth types:

- A. Biting and chewing type (Fig. 6):** This is a generalized primitive mouth type. It is used for ingesting, biting, chewing and swallowing of food. Examples: Grasshoppers, cockroaches, crickets, caterpillars, grubs etc.
1. **Labrum:** It forms the roof of the mouth cavity and is known as the upper lip.
 2. **Mandibles:** A pair of mandibles lies just below the labrum. They have teeth like structures used for grinding the food.
 3. **Maxillae:** A pair of maxillae lies below the mandibles. They are used to catch, hold and also partly grind the food.
 4. **Labium:** It forms the floor of mouth cavity and known as lower lip. It has feeler appendages known as labial palpi.
 5. **Hypopharynx:** This is tongue, and it lies in the buccal cavity. It is supposed to be an organ of taste.
- B. Piercing and sucking mouth type (Fig. 7):** Insects having this type of mouth parts suck the plant juice. Such mouth parts are found in true bugs (bed bug, red cotton bug, rice earhead bug) aphids, jassids, scale insects, mosquitoes etc.
1. **Labrum:** A very small tapering or triangular lobe often called labrum epipharynx.
 2. **Mandibles and maxillae:** They are modified to form long slender bristle like stylets which pierce into the plant or animal tissue. These stylets form two channels, one to inject the saliva, and the other to pump up the tissue fluid.
 3. **Labium:** It is modified into a 3-4 segmented long sheath also called rostrum or beak, which holds the bristle like stylets.

- C. **Chewing and lapping mouth type:** This type of mouth parts are used for taking solid and liquid food, such as pollen and nectar. Example: Honey bees.
1. **Labrum and maxillae:** They are modified to form a long cylinder or tongue. Galeae are elongated to form a pair of blade like structures. Paraglossae are greatly reduced and glossae elongated to form a united hairy tongue which terminates distally in honey spoon or labellum.
- D. **Sponging mouth type:** The mouth parts are modified for sucking up the liquid food. This type is found in the houseflies.
1. **Labrum and hypopharynx:** They form a long snout like structure which consists of a food channel.
 2. **Mandibles:** Mandibles are absent.
 3. **Maxillae:** These are represented by a pair of maxillary palpi.
 4. **Labium:** This is greatly modified to form a proboscis which has:
 - i. **Rostrum:** A proximal cone like structure bearing maxillary palpi.
 - ii. **Haustellum:** Middle portion with a mid dorsal groove serving as a food passage.
 - iii. **Labellum:** Distal oral disc.
- E. **Siphoning mouth type:** This is highly specialized for sucking up the juice from flowers. Moths and butterflies have this type of mouth parts.
1. **Labrum and mandibles:** They are greatly reduced.
 2. **Maxillae:** Maxillary palpi are rudimentary; galeae are greatly elongated and joined to form a long hollow tube which is coiled up under the head. This coiled tube stretches up to the basal portion of flowers and sucks up the nectar.
 3. **Labium:** It is represented by large hairy three segmented labial palpi and a very small basal plate.

5. ANTENNAE AND THEIR MODIFICATIONS

All insects (except Protura) possess a pair of antennae. They are sensory in function. Besides, antennae also are used as air funnel for respiration in some water beetles.

An antenna consists of the following parts:

1. **Scape:** A basal segment bearing a notch proximally.
2. **Pedicel:** The second globular segment.
3. **Flagellum:** A chain of segments after pedicel.

Antennae are of several different types:

1. **Filliform** (thread-like): All segments are of nearly uniform thickness and gradually reduce to distal end.
Example: Grasshoppers.
2. **Moniliform** (neckless-like): All segments are more or less globose and constriction occurs between the segments.
Example: Termites.
3. **Serrate** (saw-like): Segments are more or less triangular projecting in one direction.
Example: Click beetles, mango stem borers.
4. **Clavate** (club-like): Segments gradually enlarge in size towards the tip and the last segment is almost triangular in shape.
Example: Butterflies.
5. **Capitate** (knob-like): Last 2-3 segments enlarge abruptly forming a knob like structure.
Example: Sap beetles.
6. **Setaceous** (bristle-like): Each segment becomes smaller and smaller ending to a point.
Example: Cockroaches.
7. **Pectinate** (comb-like): Segments have long projections on one side and only in one direction forming a comb-like structure.
Example: Fire-coloured beetle.
8. **Bipectinate** (feather-like): Segments have long projections on both sides looking like a feather.
Example: Silk moth.
9. **Flavellate** (cobra-like): Terminal segment extends laterally and enlarges forming like a head of a cobra.
Example: Cedar beetle.
10. **Aristate** (bearing arista): It has only 3 segments; the last segment is longer and bears a bristle-like structure called arista.
Example: Housefly.
11. **Plumose**: Segments produce bunch of hairs from each joint.
Example: Male mosquitoes.
12. **Lamellate** (leaf-like): Last three segments extend in one side forming a leaf like structure.
Example: Dung beetle.
13. **Geniculate** (elbow-like): Antennae bend abruptly at an angle at the distal end of scape forming like a bent knee or elbow.
Example: Ants, weevils.

6. LEGS AND THEIR MODIFICATIONS

Insects have three pairs of legs, one pair on each thoracic segment (Fig. 4). Each leg consists of five segments (Fig. 9).

1. **Coxa:** A small basal segment which is attached freely with the pleuron and sternum through the membrane.
2. **Trochanter:** A small segment with dicondylic articulation with coxa and rigidly connected with femur.
3. **Femur:** The largest and the stoutest part of a leg.
4. **Tibia:** Long shank of a leg.
5. **Tarsus:** The last segment of a leg. In most insects, it is subdivided into 2-5 tarsomeres. Pretarsus usually ends in a pair of claws.

Insect legs are modified to perform various functions such as running, jumping, digging, swimming etc.

Leg modifications:

1. **Fossorial (Digging):** The coxa is very large, tibia is strong and tarsi with ventral pads, ending in a pair of claws which are used for digging purpose.
Example: Front legs of mole-cricket.
2. **Natatorial (Swimming):** Coxa is long, tibiae and tarsi bear hairs and flattened to form a oar like structure for swimming.
Example: Hind legs of water beetle.
3. **Raptorial (Grasping):** Coxa is elongated, femur and tibia bear rows of spines. They help in catching the prey.
Example: Fore legs of mantids.
4. **Saltatorial (Jumping):** Hind femur is greatly enlarged. The power for jumping is provided by the sudden extension of the hind tibia.
Example: Hind legs of grasshopper.
5. **Scansorial (Clinging):** Tarsus is single segmented and terminated into a powerful claw for clinging.
Example: Legs of body louse.
6. **Cursorial (Walking and running):** A typical insect leg used for walking. It has five segmented tarsus, both femur and tibia bear spines.
Example: Legs of cockroach.
7. **Polleniferous (Pollen carrying):** The femur and tibia are provided with brush like hairs. A comb in the inner side of pretarsus is used for pollen collection. A rake at the base of tibia is used for scrapping and collecting pollen in the pollen basket.
Example: Honey bee (worker).

7. WINGS AND THEIR MODIFICATIONS

Adult insects have generally two pairs of wings. The mesothorax bears the first pair (forewings) and the metathorax, bears the second pair (hindwings).

In general, a wing is full of a network of venation. Venation ranges from extensively complex network in wings of dragonflies to highly reduced and simplified system found in wasps. The veins are divided into longitudinal veins and cross veins (Fig. 10).

A. Longitudinal veins:

1. Costa (C)
2. Subcosta (Sc)
3. Radius (R)
4. Radial sector (Rs)
5. Media (M)
6. Cubitus (Cu)
7. Anal (A)

B. Cross veins:

1. Humeral (h)
2. Radial (r)
3. Sectorial (s)
4. Radio-medial (r-m)
5. Medial (m)
6. Medio-cubital (m-cu)
7. Cubito-anal (cu-a)

The primary function of wings is flight, however, there are several modifications of insect wings so that these may be used for different purposes.

Wing modifications:

1. **Elytron:** Thickened, leathery and arched forewing forming a protective armour for membranous hindwing.
Example: Beetles.
2. **Hemelytron:** Partly thickened or hardened forewing with distal portion membranous.
Example: Bugs.
2. **Stigma:** Thickened opaque spot along the costal margin of both pair of wings.
Example: Dragonflies and damselflies.
3. **Halter:** Rudimentary; hindwing slender proximally and modified into a small knob-like structure distally.
Example: Flies and mosquitoes.
4. **Fringed:** Wing having well developed fringes or long hair.
Example: Thrips.
5. **Membranous:** Thin, firm and more or less transparent wing.
Example: Dragonflies.
6. **Scaly:** Fore and hindwings are covered with scales or setae. This type of wings in moths have bristle like projection (frenulum) in hindwing or a short hook on posterior part of forewing (jugum) in butterflies.
Example: Butterflies and moths.
7. **Tegmen:** Parchment-like, thickened and leathery forewing.
Example: Grasshoppers and cockroaches.

Note: Series of minute hooks present on the anterior margin of hindwings of honeybees are called hamuli. Thickened opaque spot present on the costal margin of both pairs of wings of dragonflies and damselflies is known as stigma.

8. INTERNAL ANATOMY OF AN INSECT

DIGESTIVE SYSTEM(Fig.11):

Every cell in an insect body, regardless of its function, requires some source of energy for its maintenance, and synthesizing activities. For this it is necessary to take food, digest the same and transport the nutrients to the individual cells and throw out the undigested material (excreta).

The various parts associated to perform these processes are the mouth-parts and the alimentary canal. Between these two, there is a pair of salivary glands. The alimentary canal extends from an anterior opening (mouth) to a posterior anus. It can be divided into three distinct regions - foregut, midgut and hindgut. The fore- and hindguts possess a chitinous lining.

Foregut - Mouth or buccal cavity is followed by pharynx and oesophagus. Pharynx is an elaborate musculature concerned with ingestion and deglutition of the food. Oesophagus is a simple narrow tube leading to midgut, its hind part is symmetrically dilated to form a crop. The crop serves as a temporary reservoir for the food taken by the insect. The crop is followed by muscular proventriculus often provided with a strong cuticular plates or teeth for mixing the food.

Midgut - The most active part of alimentary canal, being concerned with digestive and absorptive functions. Opening anteriorly into midgut are 2 to 6 gastric caecae. At the junction of midgut and hindgut are malpighian tubules - numerous fine long tubes of yellow colour. They function as excretory organs.

Hindgut - It is differentiated into an anterior ileum; middle narrow curved intestine called colon and the terminal enlarged portion - rectum, which bears six rectal pads and opens posteriorly as anus. The undigested food material passes out through anus.

CIRCULATORY SYSTEM(Fig. 12):

The circulatory system in insects is rather different from that of vertebrates and many other invertebrates in that major portion of the blood or haemolymph is not found within the confines of a closed system of conductive vessels but instead bathes the internal organs directly in the body cavity. Haemolymph is a clear fluid, usually colourless or may have yellowish or greenish tinge imparted by certain pigments. It carries nutritive substance from the gut to the storage sites where these are metabolized; it also takes the excretory materials to the malpighian tubes.

The circulatory system comprises of a dorsal blood vessel and blood communicating sinuses. The dorsal blood vessel lies along the mid-dorsal body region and comprises of heart and aorta. The heart is a long-chambered yellow tube with eight pairs of lateral ostia. The aorta is a narrow tube, extending from first abdominal segment to head.

NERVOUS SYSTEM(Fig. 11):

The basic functional unit of nervous system is the nerve cell or neuron - a thin-walled tube, 45 to 50 microns in diameter.

The central nervous system of an insect consists of a double chain of ganglia connected by lateral and longitudinal connections. The anterior most ganglion commonly called brain is very complex and is located dorsal to foregut in the head. It comprises of protocerebrum, deutocerebrum and tritocerebrum. It is followed by suboesophageal ganglion and ventral nerve cord. There are 3 ganglia in thorax and 6 ganglia lying in I to V abdominal segments, the 6th one little behind. Each pair of ganglia is connected with preceding and succeeding ganglia by two longitudinal cords called connectives. The posterior most or caudal ganglion is intimately involved in the control of copulation and oviposition.

TRACHEAL SYSTEM (VENTILATORY SYSTEM) (Fig.12):

The process of taking in oxygen and throwing out carbon dioxide is known as respiration or ventilation.

Except in a few insects like springtails and some hymenopterous larvae where all gaseous exchange occurs through the integument, it is accomplished by means of an elaborate system of branching tubules commonly called tracheae. The intake of oxygen is through paired, segmentally arranged small lateral openings known as spiracles - usually one pair on thorax and 8 pairs on abdomen. The tracheae divide, sub-divide and ramify till their ultimate branches called tracheoles (0.1 to 0.2 micron in diameter) end in the tissues, where they further divide into smaller, finer, capillaries that are less than 0.1 micron in diameter.

The spiracles lead into a short, spiracular trachea that subsequently divides into a pair of dorsal tracheae, visceral tracheae and ventral tracheae. The first one lies on each side of the heart, second one lies on the alimentary canal while the ventral pair lies under the ventral nerve cord covering the ventral musculature of legs.

REPRODUCTIVE SYSTEM(Fig. 11):

Reproduction in most insects is bisexual. The male reproductive system functions in the production, storage and delivery of spermatozoa while the female produces and stores eggs, receives spermatozoa, is site of fertilization and lays eggs.

The male reproductive system is located in the posterior part of abdomen and consists of paired gonads (testes) leading to lateral ducts called vasa deferentia. Each testis consists of a number of sperm tubules or follicles called testicular follicles which contain sperms or germ cells in various stages of development. Each sperm tube leads to a vas efferens and these vasa efferentia open into the vas deferens. The two vasa deferentia unite to form median ejaculatory duct, terminal end of this duct is enclosed in an intromittent organ called aedeagus or penis. One to three pairs of accessory glands are usually associated with the ejaculatory duct; these glands secrete the seminal fluid.

The female reproductive system is also located in the posterior part of abdomen and typically consists of paired gonads or ovaries. Each ovary is composed of a number of ovarioles or egg-tubes opening at their proximal ends into oviducts. Each ovariole contains eggs in various stages of development. The ovaries are connected by lateral oviducts to a common oviduct that leads to bursa copulatrix or vagina, which opens to the exterior and receives the penis during mating. There is usually a single outpocketing from bursa copulatrix, called spermatheca in which spermatozoa received from male are stored prior to fertilization.

9. INSECT METAMORPHOSIS

Insects go through different stages of development in their life cycle and which is known as metamorphosis. In general, there are 4 basic types of metamorphosis in insects (Fig. 13,14):

1. **Ametabola** (No or simple metamorphosis): There are no differences between adults and immatures except size and some internal developmental process.
Example: Apterygotes and secondarily apterygote insects.
Stages: Egg - Young - Adult.
2. **Paurometabola** (Gradual metamorphosis): Adults differ from immatures only in having fully developed wings. Immatures gradually develop wings and become adults.
Example: cockroaches, crickets, grasshoppers.
Stages: Egg - Nymph - Adults.
3. **Hemimetabola** (incomplete metamorphosis): The immatures are aquatic and bear gills for breathing. They differ from adults in appearance.
Example: Mayflies, Dragonflies, Damselflies.
Stages: Egg - Naiad - Adult.
4. **Holometabola** (complete metamorphosis): They are completely different from the above three types. There are four stages of development. Larvae are worm-like and they do not have compound eyes. After last moult they turn into a stage known as pupa. Pupae do not eat and move.
Example: Butterflies, moths, beetles, flies, wasps, bees etc.
Stages: Egg - Larva - Pupa - Adult.

10. TYPES OF LARVAE AND PUPAE

Holometabolous insects have 4 stages of development from egg to adult. The immature stage between egg and pupa is known as **larva**, and the other one between larva and adult is called **pupa**. The larvae are generally voracious feeders where as pupae do not feed at all. There are various types of larvae and of pupae (Fig. 15).

Types of larvae:

- A. **Polypod** - They possess thoracic and abdominal legs (prolegs):
 - 1. **Pseudocaterpillar**: Larvae having 3 pairs of thoracic legs and 6 to 8 pairs of prolegs.
Example: Sawfly larvae.
 - 2. **Caterpillar**: Besides 3 pairs of thoracic legs, they possess 5 pairs of prolegs.
Example: Cabbage butterfly larvae.
 - 3. **Semilooper**: Having 3 pairs of thoracic legs and 3 pairs of prolegs.
Example: Cabbage semi-loopers.
 - 4. **Looper**: They have 3 pairs of thoracic legs and only 2 pairs of prolegs.
Example: Inch-worm larvae.
- B. **Oligopod**: Larvae that possess 3 pairs of thoracic legs.
 - 1. **Campodiform**: Larvae are elongated, somewhat flattened and legs are well developed.
Example: Lady bird beetle larvae.
 - 2. **Scarabaeidiform**: Having short thoracic legs, and c-shaped body. These larvae are known as grubs.
Example: White grubs.
 - 3. **Elateriform**: Having elongated, cylindrical long body with tough skin, popularly known as wireworms.
Example: Click beetle larvae.
- C. **Apodous**: Larvae lacking thoracic legs and prolegs.
 - 1. **Acephalous**: Head greatly reduced. These larvae are called maggots.
Example: Housefly maggots.
 - 2. **Hemicephalous**: Head slightly reduced.
Example: Honey bee larvae.

Types of Pupae:

- 1. **Exarate**: Body appendages loosely attached or free.
Example: Bees, wasps, beetles, etc.
- 2. **Obtect**: Body appendages firmly attached to the body.
Example: lemon butterfly pupa.
- 3. **Coarctate**: Pupa covered in a hardened exuviae of the last larval instar.
Example: Housefly pupa.

11. LIFE CYCLE OF HONEY BEE

(Apis indica Fabricius)

Life cycle of honey bee is very informative to understand their social behavior, communication and developmental aspects. Honey and wax are valuable products of honey bees. Besides, they also help in pollination of various crops. Thus, it is necessary to learn about bee colony and their development.

Life cycle: Honey bees are holometabolous insects that have four different stages of development.

Eggs: Queen starts laying three to four days after mating. She lays as many as 2000 eggs in a day. Eggs are creamy white in color and banana shaped. Eggs hatch in 3 days.

larvae: Known as grubs, they have no legs and eyes. All grubs feed on 'royal jelly' for the first 3 days. There after, workers and drones are given 'bee bread'. This stage remains 7 days for drone, 5 days for queen and worker.

Pupae: On about 9th day, cells containing grubs are sealed with a wax cap. Pupal stage passes inside the sealed chamber. Grub secretes a thin silken cocoon around itself. This stage lasts 8 days for queen, 13 days for worker, and 14 days for drone.

Adults: They come out from the cell by making hole through the cap. They are differentiated into 3 different castes:

Queen: She is bigger in size than drones and workers. Queen is the only fertile female in a hive, hatched from fertile eggs. Her grub stage is specially fed on royal jelly. Her duty is to lay eggs and regenerate the colony.

Drones: They are intermediate in size. They develop parthenogenetically from the unfertilized eggs. They fertilize queen and may sometimes also regulate the temperature inside the hive.

Workers: They are the smallest members of the colony, coming out of fertile eggs, but unable to reproduce. Workers possess various structures in their legs such as comb, pollen press, and pollen basket. They perform various activities, like secretion of wax and comb foundation, cleaning of cells in which queen lays eggs, feeding the queen and grubs, collecting pollen and nectar, producing honey, regulating temperature and guarding hive against robber bees.

12. MODERN BEE HIVE AND ITS PARTS

Honey bees live in a colony and produce valuable products such as honey and wax. Knowing the value of honey and wax, people thought of domesticating the bees by rearing them in artificial be hives. The scientific way of bee keeping started in 1851 with the invention of modern bee hive by Lorerzo L. Langstroth.

It is necessary to have an idea of modern bee hive for better management of honey bees and thereby insuring good honey and wax production. A modern bee hive has following parts:

1. **Base (stand):** It protects the hive from moisture and unnecessary wear and tear.
2. **Floor stand:** A basal lover of the hive with a bee entrance in it. When new bee colony introduced in a hive, a thin metal sheet with holes known as queen gate is provided to prevent queen from going out.
3. **Brood chamber:** A rearing chamber where queen, workers and drones live together. Frames (wooden bars) are provided with proper spacing for the movement of queen and workers in each frame.
4. **Queen excluder:** A wire screen, metallic sheet or a thin wooden plank with holes is placed between the super and the brood chamber to prevent the queen entering into the super.
5. **Super:** A chamber similar to the brood chamber but a little short in height, placed on queen excluder. Only the workers can reach into this chamber where they store honey.
6. **Inner cover:** Upper base with holes on it for proper ventilation and bee scape. It also serves as space for top feeding.
7. **Top cover:** Thatched roofed wooden block placed on the inner cover for protecting hive from sun and rain.

13. LIFE CYCLE OF MULBERRY SILKWORM (Bombyx mori Linnaeus)

Silk is a very valuable commodity. It has been used by royal families and rich people from the ancient time. The best quality of silk is obtained from the mulberry silkworm, Bombyx mori Linnaeus. This insect passes through a complete metamorphosis.

The study of life cycle is very important in order to be familiar with its various stages of development so that proper care and feeding can be done during the larval instars, for higher and better quality of cocoon production.

Life cycle:

Eggs: Female lays 300-400 eggs on mulberry leaves or artificially prepared butter cups. Eggs are oval in shape and creamy white in color. They hatch in 9-11 days. Proper temperature and humidity should be maintained for good hatching.

Larvae (caterpillars): Newly hatched larvae are black or dark brown in color and become smoother and lighter during different succeeding instars. There are five larval instars - first two instars are known as young worms and rest three instars are called grown up worms. Larvae after last moult, raise their head and search a shelter for resting. They secrete silken thread and cover themselves. Larval stage lasts for 18-24 days.

Pupae: This is the resting stage or inactive stage in which pupae remain covered in the silken cocoon. It lasts for 11-14 days.

Adults: Adults come out by making a small hole through the cocoon. They do not eat during their short life span.

14. LIFE CYCLE OF LAC INSECT (Kerria lacca) (Kerr)

Lac is a resinous secretion of a tiny lac insect. It has been used for various preparations such as surface coating, mirror backing, printing drawing, hair liquers, gramophone records, electric goods etc.

Life cycle study of a lac insect provides an information on their developmental stages which could be very useful for inoculation, harvest and other management aspects.

Life cycle: This insect passes through a gradual metamorphosis and has 3 different stages:

Eggs: Oviposition starts just after mating. Eggs are laid in cells inside in crustation. A female lays 300-1000 eggs and dies soon after oviposition. Eggs start hatching within a few hours.

Nymphs: They thrust hair like proboscis up to the phloem of host plants and derive their nutrition. Once settled, they do not move about. Nymphs have 3 moults. After first moult they loose their antennae, legs and eyes. These appendages are again developed after second moult. Nymphs are encaged in their own secretion, and cell size increases with the increase in the growth of lac insect. Nymphal stage lasts for about two months.

Adults: A short time after emergence, mating takes place and female continues laying eggs.

15. CLASSIFICATION OF INSECTS

Carolus A. Linnaeus was the first to name insect species and suggest a simple classification. He also evolved the binomial nomenclature to name the various identified organisms. Since then so many taxonomists have suggested various improvements and naturally there have also been difference of opinions. So it is not surprising that tables of classification given by various authors differ from one another in many respects. At present there are as many as 32 Orders under class Insecta.

The Class Insecta is divided into 2 sub-classes: **APTERYGOTA** or **Ametabola** (without wings and no metamorphosis) and **PTERYGOTA** or **Metabola** (having wings and metamorphosis); the latter is again splitted into two divisions, namely **EXOPTERYGOTA** or **Hemimetabola** (nymphs having wing-pads and simple metamorphosis) and **ENDOPTERYGOTA** or **Holometabola** (wings develop internally and complete metamorphosis). The most important Orders from agricultural point of view are:

Apterygota	1. Thysanura (700 spp.): Silverfish
Exopterygota	2. Odonata (5000 spp.): Dragonflies, damselfies
	3. Orthoptera (25000 spp.): Grasshoppers, crickets
	4. Isoptera (2100 spp.): Termites
	5. Thysanoptera (4500 spp.): Thrips
	6. Hemiptera (40000 spp.): True bugs
	7. Homoptera (5000 spp.): Cicadas, aphids, jassids
Endopterygota	8. Coleoptera (290000 spp.): Beetles, weevils
	9. Diptera (87000 spp.): Flies
	10. Lepidoptera (125000 spp.): Moths, butterflies
	11. Hymenoptera (120000 spp.): Ants, bees, wasps
	12. Siphonaptera (1100 spp.): Fleas

1. **THYSANURA:** Primitive wingless insects having elongate body and chewing type of mouth parts; antennae long and many segmented; three tail-like appendages at the end of abdomen (a pair of cerci and a median caudal filament); body covered with scales. Silver fish is a pest of books and papers.

2. **ODONATA:** Mouth parts chewing, matamorphosis simple; nymphs aquatic. Adults have two pairs of elongate membranous, many-veined wings; forewings and hindwings similar in size and shape (Damselflies) or hindwings broader at the base than fore wings (Dragonflies). Abdomen long and slender; compcund eyes large, occupying most of the head; antennae very short bristle-like and inconspicuous. Copulatory organs of male located on ventral side of 2nd abdominal segment. Cerci present and in males, functioning as clasping organs during mating.

3. **ORTHOPTERA:** Mouth parts biting and chewing; metamorphosis simple. Antennae hair-like, many-jointed and often long. Forewings (tegmina) long, narrow, many-veined and somewhat thickened; hindwings membranous, broad with many veins, when at rest folded fan-like under the forewings. Cerci present. Grasshoppers, cockroaches, crickets, mantids.

4. **ISOPTERA:** Mouth parts chewing. Metamorphosis simple.
Small, soft-bodied and usually pale coloured. Social insects with caste differentiation - workers, soldiers, queen and the reproductive forms. Antennae short and thread-like. Winged or wingless - winged forms with both pairs of wings membranous and similar in size and shape. Termites are polyphagous pests.
5. **THYSANOPTERA:** Mouth parts rasping and sucking type and asymmetrical (right mandible reduced). Metamorphosis intermediate between simple and complex. These are slender, fragile insects, minute in size, 1 to 2 mm long; pale to blackish in colour. All the four wings are long, narrow, heavily fringed and having no veins. Thrips are polyphagous pests.
6. **HEMIPTERA:** Mouth parts piercing and sucking. Metamorphosis simple. Beak generally arises from anterior part of head. Forewings thickened at base, membranous at tip; hindwings membranous and shorter than forewings. All true bugs.
7. **HOMOPTERA:** Mouth parts piercing and sucking. Metamorphosis simple. Beak short and arises from hind part of head. Forewings uniform in texture - membranous or thickened. Aphids, cicadas, whiteflies.
8. **COLEOPTERA:** Mouth parts chewing. Metamorphosis complete. Forewings horny or leathery nearly always meeting in a straight line down back and covering hind wings; hind wings membranous, longer than fore wings and folded beneath the forewings when not in use. Beetles and weevils.
9. **DIPTERA:** Mouth parts sucking (rarely vestigial). Metamorphosis complete. One pair of wings borne on mesothorax; hindwings reduced to knob-like structures called halteres. Antennae short and inconspicuous. Compound eyes large, sometimes meeting on dorsal side of head. Houseflies.
10. **LEPIDOPTERA:** Mouth parts sucking, proboscis a coiled tube. Metamorphosis complete. All four wings membranous and covered with scales; antennae long, slender and always knobbed in butterflies. Butterflies, moths and skippers.
11. **HYMENOPTERA:** Mouth parts chewing and lapping type. Metamorphosis complete. Wings when present, membranous with relatively few veins. Females with a ovipositor, often longer than body and sometimes modified into a sting. Bees, ants, wasps and sawflies.
12. **SIPHONAPTERA:** Small wingless insects, generally less than 5 mm in length and living as ectoparasites on birds and mammals. Body heavily sclerotized and laterally flattened; antennae short and legs relatively long. Fleas.

Classification of insect Orders

ORTHOPTERA (Fig. 23):

Acrididae: Pronotum not prolonged over the abdomen. Wings well developed. Tarsi 3-segmented. Short-horned grasshoppers (Locusts, rice grasshopper); they feed on various crops; locust may cause havoc.

Tettigoniidae: Forewings broadly oval, somewhat convex; prosternum with a pair of short spines; pronotum as long as wide with two transverse grooves. Long-horned grasshoppers; some are serious pests on rice, maize and other crops.

Gryllidae: Somewhat flattened insects; tarsi 3-segmented. Ovipositor long and cylindrical; cerci long and feeler-like. Field-cricket and house-cricket are serious pests.

Mantidae: Prothorax and front coxae greatly elongated. Mantids are the predators i.e. beneficial insects.

Blattidae: Body flattened and oval; head concealed from above by pronotum; antennae very long and slender. Cockroaches are common household pests.

HEMIPTERA (Fig. 24):

Cimicidae: Flat, oval, reddish-brown bugs, 3 to 6 mm long; antennae 4-segmented; tarsi 3-segmented. Wings vestigial. Bed bugs suck the blood of man and other animals.

Miridae: Small, elongated and oval in shape, soft-bodied, bright coloured bugs; beak 4-segmented, tarsi 3-segmented and forewings with a cross. Leaf bugs or plant bugs; some are major pests of grapes, apple, sorghum, and tea.

Tingidae: Small insects less than 5 mm in length and greyish in colour; body and wings have reticulate sculpturing; antennae and beak 4-segmented; pronotum has a triangular posterior extension over scutellum. Ocelli absent. Lacewing bugs feed on foliage of number of economic and wild plants.

Lygaeidae: Medium sized, 8 to 12 mm long, elongate or oval in shape, conspicuous by red white or black spots; antennae 4-segmented; ocelli present; tarsi 3-segmented with a pad at base of each claw; rostrum 4-segmented. Membranous portion of forewings has only 4-5 veins. These bugs are polyphagous pests causing serious damage to cereals, cotton, groundnut, etc., a few are predaceous on other insects.

Pyrrhocoridae: Similar to Lygaeid bugs but no ocelli and more veins in membranous portion of hindwings; brightly coloured in red with black markings. Red cotton bug is polyphagous pest of cotton, okra, etc.

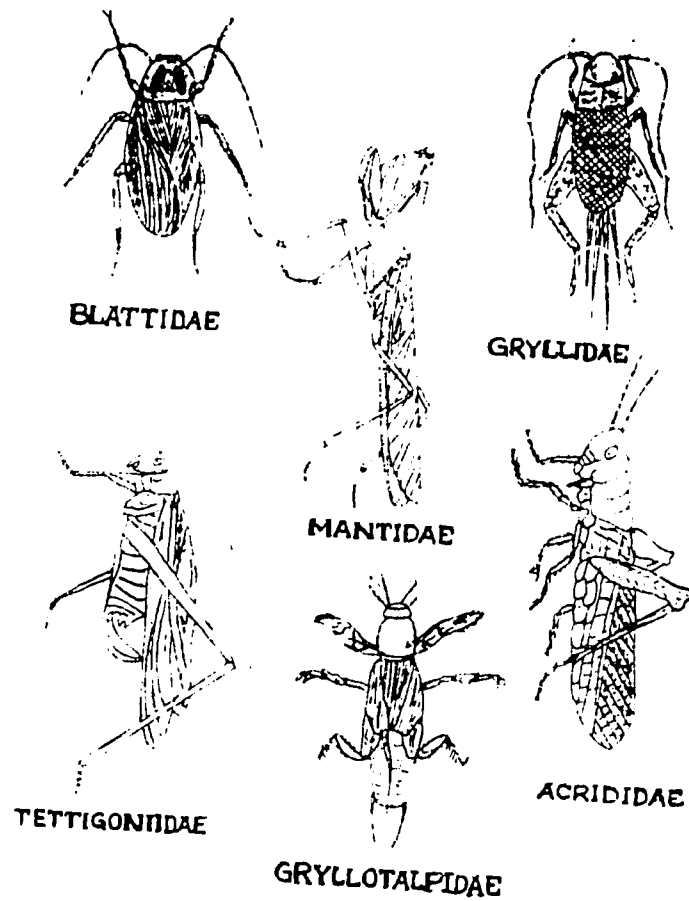
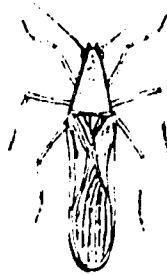


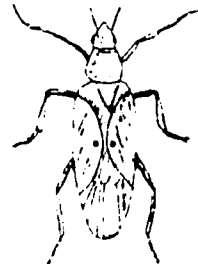
Fig. 23. FAMILIES OF ORTHOPTERA



LYGAEIDAE



COREIDAE



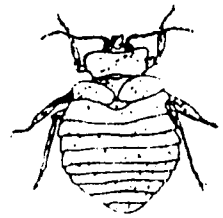
PYRRHOCORIDAE



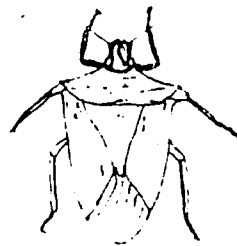
MIRIDAE



TINGIDAE



CIMICIDAE



PENTATOMIDAE

Fig. 24. FAMILIES OF HEMIPTERA

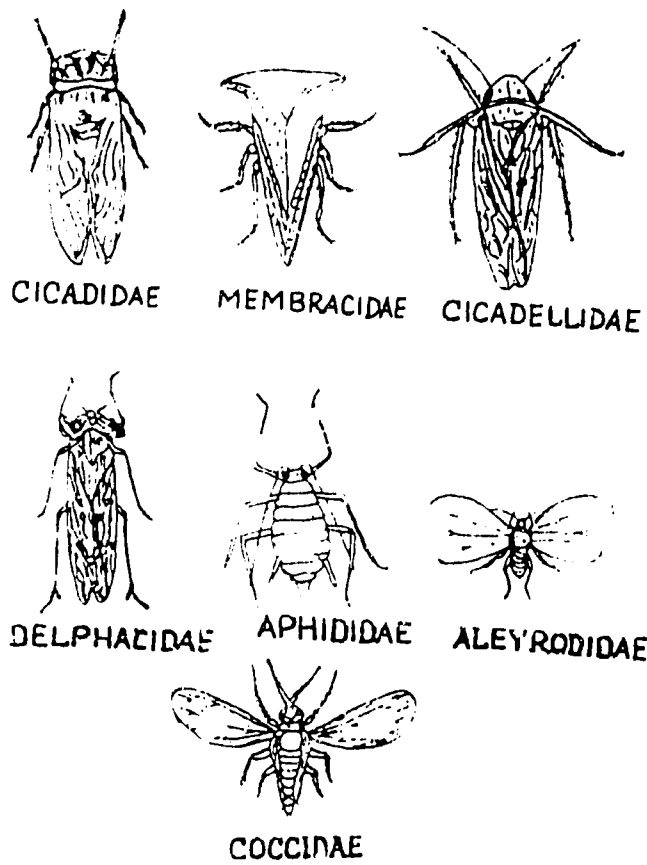


Fig. 25. FAMILIES OF HOMOPTERA

Coreidae: Medium to large size (over 10 mm in length), dull dark coloured bugs; head narrower than pronotum; antennae inserted well up on sides of head; rostrum 4-segmented; hind tibia dilated and leaf-like. These phytophagous bugs have been reported as pests of various crops including rice, fruits and vegetables.

Pentatomidae: Broadly oval and somewhat shield-shaped, over 6 mm in length and brightly coloured bugs; antennae 5-segmented; scutellum large and triangular; tibia with weak or no spines. Produce a disagreeable odour. Stink bugs are mostly polyphagous pests, a few are also predaceous on other insects.

HOMOPTERA (Fig. 25):

Cicadidae: Non-jumping large insects 30 to 50 mm long; forewings membranous. Males have sound producing organs at the base of abdomen on ventral side. Cicadas are common in forests, where they lay eggs on trees by making long slits.

Membracidae: Small jumping insects 12 mm or less in length. Pronotum conspicuously prolonged backwards over abdomen. A large number of treehoppers and cowbugs may be seen sucking the sap on tree trunks.

Cicadellidae: Small jumping insects, less than 10 mm long; body usually tapering posteriorly. Rice leafhoppers are the most common pests.

Delphacidae: Small, short winged insects having large apical spur on hind tibia. Planthoppers are serious pest of rice.

Aleyrodidae: Minute, whitish insects, 2-3 mm long; body and wings covered with mealy powder. Hindwings nearly as long as forewings; the wings held horizontally over the body at rest. Cotton whitefly and citrus whitefly are some of the common pests.

Aphididae: Soft-bodied, usually pear-shaped, 4 to 8 mm long with a pair of cornicles near posterior end of abdomen. Both winged and wingless. Mustard aphid and green peach aphid are some of the serious pests.

Coccidae: Minute inconspicuous and highly specialized insects. Females are wingless, legless and sessile. Antennae often atrophied; body segmentation obscure; rostrum short; many species covered with wax or powdery coating. Males have 10 to 25 segmented antennae and usually a pair of wings; Mouth parts in males atrophied. Mealy bugs and scale insects are polyphagous pests; lac insect is beneficial.

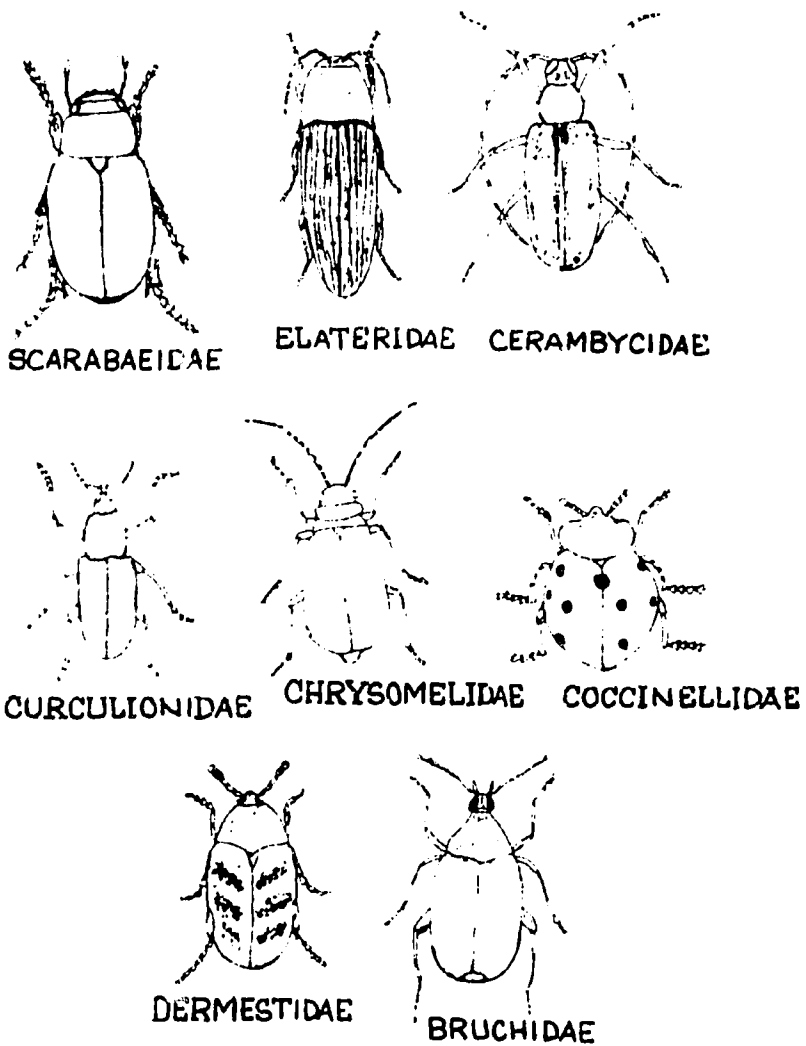


Fig.26. FAMILIES OF COLEOPTERA

COLEOPTERA (Fig. 26):

Dermestidae: Elongate to broadly oval; often covered with scales or hair; antennae short, clubbed fitting in grooves below sides of pronotum. Khapra beetle is a pest of stored grains.

Elateridae: Body elongate-narrow, somewhat flattened, usually parallel-sided and rounded at ends; antennae serrate; posterior corners of pronotum prolonged backwards into sharp points; forewings slightly pointed at tips. Click beetles and wireworms feed on decaying vegetation and dead wood.

Coccinellidae: Small, broadly oval to nearly spherical, convex dorsally, nearly flat ventrally. Head partly or completely concealed by pronotum. Often brightly coloured; yellow, orange or red with black markings. Antennae short and club-shaped. Predators on aphids, whiteflies and scale insects.

Scarabaeidae: Elongate-oval, short, heavy and usually convex body; antennae 8-11 segmented, mostly lamellate, rarely flabellate. Chafer beetles are the major pests of various crops.

Cerambycidae: Body elongate and cylindrical. Eyes generally notched and antennae arising in the notch; antennae always more than half as long as body. Mango stem borers bore into stems of mango trees causing severe damage.

Chrysomelidae: Body generally oval in shape; eyes not notched; antennae less than half as long as body. Red pumpkin beetles and tortoise beetles are the worst pests of vegetables.

Bruchidae: Egg-shaped body, broadened posteriorly; head concealed from above and prolonged into short broad snout; antennae clubbed but sometimes serrate or pectinate. Elytra always short exposing tip of abdomen. Pulse beetles feed exclusively on legume seeds.

Curculionidae: Head prolonged into a well developed snout; antennae clubbed and nearly always elbowed; mouth parts small and partially hidden. Rice weevil, banana stem weevil, mango weevil and sweet potato weevil are major pests.

DIPTERA (Fig. 27):

Culicidae: Wings long and narrow with scales along veins and wing margins. Mosquitoes bite human beings and transmit malaria causing organisms.

Cecidomyiidae: Minute delicate insects with long legs, moniliform antennae and legs. Wing venation is greatly reduced to a few longitudinal veins; cross veins absent. The gall midges have diverse habits; some are parasitic or predaceous on aphids and coccids, many are phytophagous (rice gall midge, mango gall midge), and a few are saprophagous.

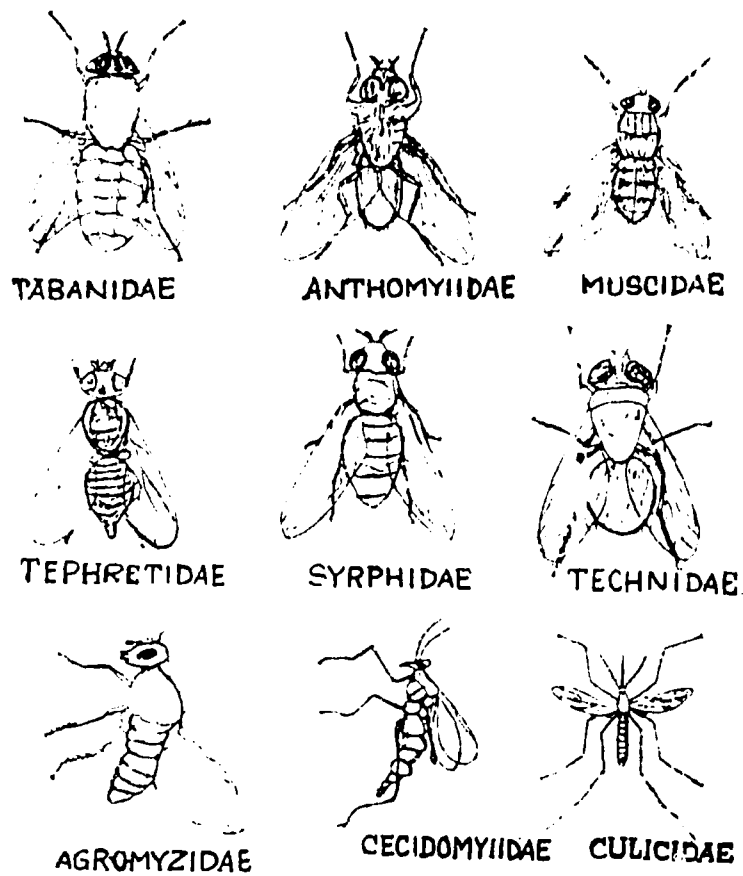


Fig. 27. FAMILIES OF DIPTERA

Tabanidae: Stout bodied, medium sized (10 to 20 mm long) flies; third antennal segment elongate; eyes very large with golden-green or purple marks. Females suck blood, while males feed on nectar.

Syrphidae: Brightly coloured flies. Frontal suture absent; antennae 3-segmented, flagellum usually with single enlarged segment. Many are predaceous on aphids and other Homoptera nymphs.

Tephretidae: Small to medium size, brightly coloured. Wings usually spotted or banded. Fruitflies are the most common pests of a large number of fruits.

Agromyzidae: Small to minute flies, black or yellow in colour. Their larvae mine the leaves. Pea leaf miner and pea stem fly are the major pests of vegetables.

Anthomyiidae: Small, elongated flies, atleast one pair of fronto-orbital bristles bent upwards and with no dorso-central bristles in anterior part of mesonotum. Sorghum shootfly is a serious pest of young sorghum plants.

Muscidae: Medium sized flies with fleshy proboscis and bristles on mesonotum. Houseflies are a nuisance and vectors for several diseases of man including cholera and typhoid.

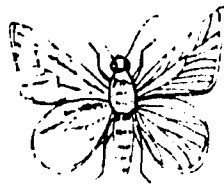
Tachinidae: Small to medium sized, brown to black in colour with well developed hypopleural and pteropleural bristles; prominent post-scutellum and abdomen covered with bristles. These are endoparasites of various larvae and pupae, hence beneficial.

LEPIDPTERA (Fig. 28):

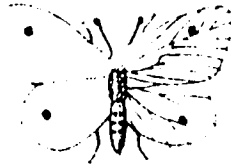
Gelechiidae: Small sized moths; fore wings narrowly rounded or pointed at apex; hind wings somewhat trapezoidal. Potato tuber moth, pink bollworm and groundnut leaf miner are the major pests of potato, cotton and groundnut respectively, while angoumois grain moth attacks stored grains.

Tortricidae: Small, grey or brown coloured moths; fore wings rather square-tipped; Cubitus vein (Cu) in hind wings lacking; when at rest the wings are held roof-like over the body. Polyphagous pests of tea, cotton, castor, etc.

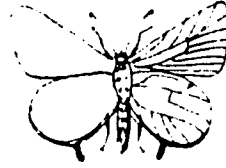
Pyralidae: Small, delicate moths; fore wings elongated-triangular with vein Cu appearing 4-branched and hind wings usually broad and rounded. Feeding habits of larvae vary greatly; some young ones feed on foliage then bore inside the stems, others feed on roots or stored grains and a few are even aquatic. This includes a large number of pests like sugarcane borers, rice borers, etc.



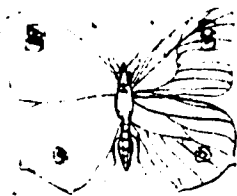
HESPERIIDAE



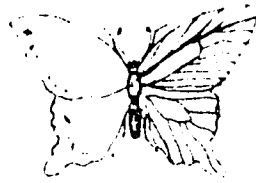
PIERIDAE



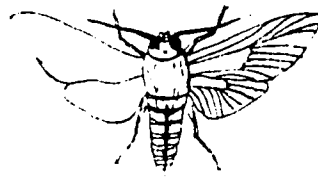
LYCAENIDAE



NYMPHALIDAE



PAPILIONIDAE



SPHINGIDAE



ARCTIIDAE



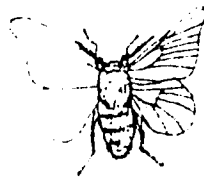
NOCTUIDAE



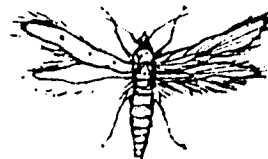
TETRACIDAE



PYRALIDAE



BOMBYCIDAE



GELECHIIDAE

Fig. 28. FAMILIES OF LEPIDOPTERA

Nymphalidae: Brightly coloured butterflies that have greatly reduced fore legs which are non-functional and generally folded on thorax; short tibia covered with long hairs. Forewings relatively broad and triangular; hindwings with two anal veins. The caterpillars of these beautiful butterflies are defoliators of castor, mango, and various flowering shrubs.

Lycaenidae: Small delicate brightly coloured butterflies; upper surface or wings being metallic blue or dark brown; forelegs of males usually reduced and tarsal claws not forked; tail-like delicate prolongations on hindwings. This includes some major pests of pulses and fruit trees.

Pieridae: Medium sized butterflies, white or yellow coloured sometimes even orange with black spots. Forewings with Cu 3-branched; hindwings with 2 anal veins; tarsal claws forked. Cabbage-butterfly larvae are major pest of cruciferous crops.

Papilionidae: Large and conspicuously coloured butterflies. Forewings with vein Cu 4-branched; hindwings with one anal vein and a tail-like prolongation. Lemon butterfly is the most common and serious pest of Citrus spp.

Hesperiidae: Stout bodied, strong fliers. Head as wide as or wider than thorax; antennae are widely separated at the base and are apically prolonged beyond the club into a hook; hind tibia with two pairs of spurs; wing-span less than 30 mm. Rice skipper is a serious pest various economic crops.

Sphingidae: Proboscis and frenulum well developed and without tympanal organs; antennae thickened towards and beyond middle but apically pointed and hooked. Forewings are elongate, outer margin being oblique. Death's head moth is a remarkable species; it enters beehives and sucks the honey.

Noctuidae: Heavy-bodied moths; antennae not knobbed apically; ocelli present; forewings somewhat narrowed, smoothly scaled and with single complete anal vein; hindwings broadened with large basal areole and without humeral veins; frenulum well developed; wing spread 25 to 50 mm. These moths are nocturnal in habit and attracted to light. Fruit sucking moths suck the juice of various fruits including Citrus spp.

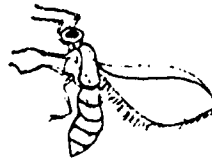
Saturniidae: Antennae variable and not dilated apically. Wings scaled throughout; forewings with a single complete anal vein and hindwings with one or two anal veins; much broader than their fringe and wider than fore wings; frenulum vestigial or absent. Wings-spread 25 to 150 mm. Tasar silkmoth and its allied species yield silk, but there are some that feed on foliage of various temperate fruit trees.



TENTHREDINIDAE



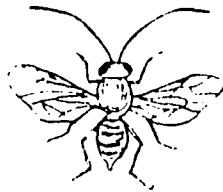
FORMICIDAE



TRICHOGRAMMATIDAE



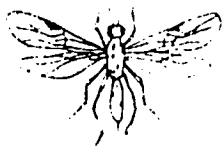
CHALCIDIDAE



CYNIPIDAE



ICHNEUMONIDAE



BRACHONIDAE



VESPIDAE



APIDAE

Fig.29 FAMILIES OF HYMENOPTERA

HYMENOPTERA (Fig. 29):

Tenthredinidae: Antennae thread-like and 9-segmented. Forewings with 1 or 2 marginal cells and without any intercostal veins. Eight pairs of abdominal legs in larvae of sawflies. Mustard sawfly is the most destructive pest of mustard, radish, turnip, etc.

Formicidae: Antennae strongly elbowed. First abdominal segment with a dorsal hump. Social insects - Queen and winged males, and wingless workers. Ants are a real nuisance.

Trichogrammatidea: Tiny wasps (0.3 to 2.0 mm long); antennae less than one mm long and 3- to 8-segmented. Tarsi 3-segmented. Forewings without closed cells. Larvae are egg parasites - Trichogramma minutum Riley is the most common.

Chalcididae: Small insects, 2 to 6 mm long, uniformly dark coloured. Hind femora greatly enlarged; hind coxae considerably larger than front coxae. Ovipositor usually short. Larvae are egg-parasites of various insects.

Cynipidae: Small, black wasps, 3 to 8 mm long; antennae 11- to 16-segmented. Hindwings possess 2 or 3 nervures. Abdomen oval, shiny and somewhat compressed. Larvae cause small galls on plants which serve as shelter and they feed in these galls.

Ichneumonidae: Large, slender, black yellow or reddish-yellow insects; antennae at least half the body length, having 16 or more segments. Two recurrent veins in forewing and absence of anal lobe on hindwing. Larvae are internal parasites mainly on immature stages of Lepidoptera but often parasitize the larvae of Coleoptera and Hymenoptera.

Braconidae: Small, stout-bodied insects, brownish or black in colour. Forewings have one or none recurrent veins; costal cell absent; ovipositor often very long. Larvae are common internal or external parasites, primarily on larvae of Lepidoptera and Coleoptera.

Vespidae: Pronotum more or less triangular; antennae usually thread-like, 12-segmented in females and 13-segmented in males. First discal cell in forewings half as long as wing. Wings folded longitudinally at rest. Ovipositor apical and functioning as a sting. Wasps - a few are predaceous upon other insects.

Apidae: Body hairy, hairs branched or plumose. Three submarginal cells in forewings; jugal lobe in hindwings shorter than submedian cell, rarely lacking. Honey bees, besides producing honey and wax, are valuable pollinators.

Hierarchical system of classification

The largest biological unit is called Kingdom which comprises of two divisions - Plant Kingdom and Animal Kingdom. These are further divided into subdivisions called Phyla. Insects and their immediate relatives belong to the phylum Arthropoda (jointed-foot) and on further division the insects come under class Hexapoda (six-legged). Classes are divided and sub-divided into orders, super-families, families, sub-families, genera and ultimately the species. This classification of insects follows certain rules and regulations which are outlined in 'The International Code of Zoological Nomenclature'.

Scientific names are written in Latin all over the world. A species name consists of two words - generic and specific. This is known as 'binomial nomenclature' and was first suggested by Carolus Linnaeus. These names are always printed in italics or underlined. The scientific name is followed by name of the scientist who first described and christened the species. This name is not italicized or underscored.

Standard word-endings are used for certain taxa e.g., Order names of winged insects usually end in -ptera (Hymenoptera), super-family in -oidea (Apoidea), family in -idae (Apidae), sub-family in -inae (Apinae) and tribe names end in -ini (Xylocopini).

Hierarchy of generally accepted taxonomic categories:

Kingdom: Animalia
Sub-kingdom: Metazoa
Division: Enterozoa
Phylum: Arthropoda
Sub-phylum: Invertebrata
Class: Insecta (Hexapoda)
Sub-class: Pterygota
Division: Endopterygota
Order: Hymenoptera
Sub-order: Apocrita
Super-family: Apoidea
Family: Apidae
Sub-family: Apinae
Tribe: Xylocopini
Genus: Apis
Species: indica
Author: Fabricius
S.name: Apis indica Fabricius
Common name: Honey bee.

16. PESTICIDES

Pesticides are the chemicals that kill the pests. These may be acaricides, insecticides, herbicides, fungicides, ovicides, rodenticides etc. The chemicals used for killing or checking the insect population are called insecticides. Insecticides have been in use since time immemorial (200 BC) but their regular use dates back to 1865 when Paris green was used against Colorado beetle on potato in USA. Till the discovery of insecticidal properties of DDT (dichloro-diphenyl-trichloroethane), the inorganic chemicals and a few plant products dominated the field of pest-control. With the discovery of DDT followed by BHC (benzene hexa-chloride) in 1941 the entire concept of insect control was revolutionized. During the last four decades phenomenal progress has been made in the development of synthetic insecticides with the addition of organo-phosphates, carbamates and more recently synthetic pyrethroids.

Classification of insecticides

Insecticides have been classified in several different ways. Earlier classification was based on action or manner in which the chemicals acted and killed the insect. Thus, three groups were recognized - stomach poisons, contact poisons and fumigants. With the advent of a large number of insecticides, many of these having more than one mode of action, it became difficult to classify them. So the present classification is based on the chemical nature of the toxicants.

Broadly, the insecticides fall in two groups - Inorganic and Organic. Inorganic compounds include, lead arsenate, calcium arsenate, paris green, sodium fluosilicate etc. These are the most persistent chemicals. Their residues are gradually removed by washing and weathering. These are no more in use for the last three decades.

Organic insecticides are further grouped into Botanicals (plant origin), Carbamates, Organo-chlorines, Organo-phosphates and Synthetic Pyrethroids.

Botanicals are the toxicants derived from plants, such as nicotine, pyrethrins, rotenone, ryania etc. These are either stomach or contact poisons or both. Though these are non-persistent and very safe to use, but because of their low efficacy in controlling the pests, these are not in much use now-a-days.

Carbamates are more potent insecticides and very much in demand. Those commonly used are aldicarb (Temik), carbaryl (Sevin), carbofuran (Furadan) and Zectron. Carbaryl is a non-specific insecticide effective against a wide spectrum of pests including those that have become resistant to organo-chlorines. It acts as contact and stomach poison and has longer residual effect than most of the organo-phosphates.

Organo-chlorines or chlorinated hydrocarbons as these are commonly known, have been in use for last four decades. These include BHC, DDT, aldrin, dieldrin, chlordane, endosulfan, endrin, heptachlor, toxaphene etc.

Organo-phosphates are the most popular pesticides and have a wide range of insecticides in the market. Some of these are, diazinon (Basudin), dichlorvos or DDVP (Nuvan), dimethoate (Rogor), disulfoton (Disyston), fenitrothion (Folithion), malathion, mevinphos (Phosdrin), monocrotophos (Nuvacron), parathion-ethyl (Folidol), parathion-methyl (Metacid), phorate (Thimet), oxydemeton-methyl (Metasystox), phosphamidon (Dimecron), quinalphos (Ekalux) and thiometon (Ekatin). These act mainly as contact and stomach poisons, though some are systemic and a few also have fumigant action. All these are very effective against a large spectrum of insect species but except malathion and fenitrothion, others are highly toxic and should be used with extra care.

Synthetic pyrethroids have come into market recently. These are all contact poisons having good knock-down effect, long residual effect, low mammalian toxicity and minimum atmospheric pollution. But these are not effective against sucking pests and hasten the maturity of crop which may not be desirable. The commonly available products are, cyfloxylate (Baythroid), cypermethrin (Ripcord), decamethrin (Decis), fenpropathrin (Meothrin), fenvalerate (Sumicidon), flucythrinate (Pay-off), fulvalinate (Mevrik) and permethrin (Ambush).

Due to the tremendous increase in use of pesticides many countries have expressed grave concern over the possible effects of pesticide contamination on 'balance of nature'. The organo-chlorines and organo-phosphates have been reported posing a potential threat to all types of ecosystem.

Note: Names in parenthesis are trade names.

Dilution of pesticides

Pesticides are available in the market in various formulations, such as dusts, wettable powders (or water dispersible powders), emulsifiable concentrates, granules and so on. Usually the emulsifiable concentrates and wettable powders contain high concentrations of the active ingredients. It is therefore necessary to dilute these formulations at time of application.

Pesticides are generally recommended as:

1. The active ingredient (a.i.) per unit area
2. Percentage of active ingredient in the final spray solution or mixture.

The following formulae and examples will illustrate these points:

1. Pesticide recommendation based on active ingredient (a.i.) per unit area.

Formula:

$$\text{Amount of pesticide (litre or kg)} = \frac{\text{Area to be treated (ha)} \times \text{Amount a.i. (kg/ha)}}{\text{Concentration of the formulation (a.i. in the formulation)}} \times 100$$

Example 1:
 Malathion is recommended at the rate of 2 kg a.i./ha for the control of armyworm in maize. Calculate the amount of Cythion (50% EC) required for 5 ha (Cythion is the trade name of malathion).

$$\text{Amount of cythion (50\% EC)} = \frac{5 \times 2}{50} \times 100 = 20 \text{ litres}$$

or 20 kg (The specific gravity of Cythion is assumed to be 1).

Example 2:
 To control the stem borers on rice, 1 kg a.i./ha of Furadan is recommended. Calculate the amount of Furadan (3% Gr) for 15 ha.

$$\text{Amount of Furadan 3\% G (kg)} = \frac{15 \times 1}{3} \times 100 = 500 \text{ kg.}$$

2. Pesticide recommendation based on % of the active ingredient in the final spray mixture

Formula:

$$\text{Amount of Pesticide (litres or kg)} = \frac{\text{Concentration of spray mixture} \times \text{Volume of spray needed}}{\text{Concentration of the pesticide formulation (a.i. of the product)}}$$

Example 1:
 For the control of rice earhead bug, 0.05% methyl-parathion is recommended. Calculate the amount of Metacid (50% EC) for 600 litres of water (Metacid is the trade name of methyl-parathion).

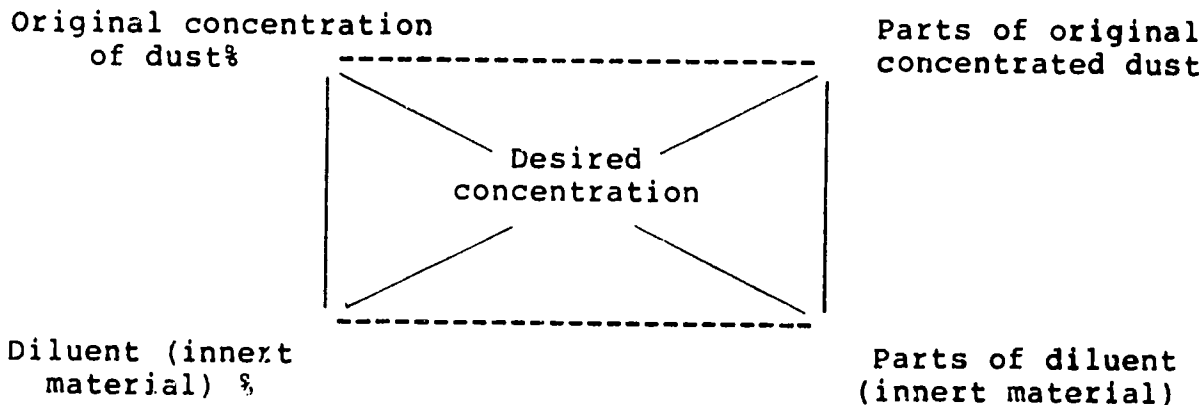
$$\text{Amount of Metacid (50\% EC)} = \frac{0.05 \times 600}{50} = 0.6 \text{ litres}$$

Example 2:
 Cotton jassids are controlled with 0.2% carbaryl. Calculate the amount of Sevin (50% WP) for 600 litres of water (Sevin is the trade name of carbaryl).

$$\text{Amount of Sevin (50\% WP)} = \frac{0.2 \times 600}{50} = 2.4 \text{ kg}$$

Dilution of concentrated dust formulations:

Quite often dusts are formulated in high concentrations for the ease of transportation. They need to be diluted before application using inert materials such as talcum powder or fine clay dust. The following square method can be very easily used for diluting concentrated dust formulations.

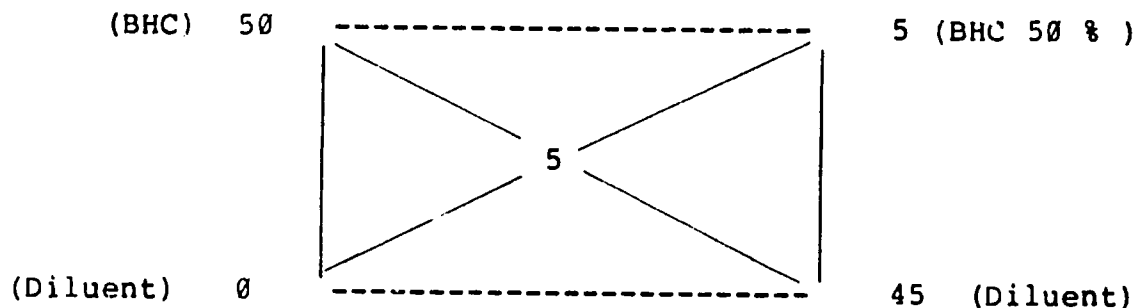


Example:

For the control of rice earhead bug, 5% BHC dust is recommended. But only 50% BHC dust is available in the market. Now you have to dilute it to 5% dust with some diluent. Calculate the proportion of 50% BHC dust and the inert diluent in the final product (i.e. 5% BHC dust).

Here, Original concentration of BHC dust	= 50%
Concentration of inert diluent	= 0%
Desired concentration of the final product	= 5%

Now, put these figures on the square as below:



Subtract the central figure (in this case, 5) diagonally. Now, the numbers on the right hand side corners of the square (5 and 45) show the proportions of the respective materials, i.e. 5 parts of 50 % BHC and 45 parts of diluent to make a total of 50 parts of the desired product, that is 5 % BHC.

17. PESTICIDES APPLIANCES

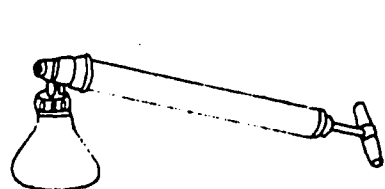
ATOMISER (Fig. 30): This is the smallest and simplest sprayer. There is tin, plastic or glass container with a capacity of less than half litre. It is fitted with a small nozzle and a pump to be operated by hand. With each forward stroke of the pump, the fluid is discharged through the nozzle in fine droplets. The spraying is not continuous and it is used only in laboratories, glasshouses and houses.

HAND SPRAYER (Fig. 30): This is a small single action sprayer. Capacity of the tank is about one litre. After filling the three-fourth of tank, give 8-10 strokes of the pump-piston to build up the pressure. Press the lever and the nozzle gives you a continuous fine mist spray. Good for kitchen-gardens and laboratories or glass-house work.

KNAPSACK SPRAYER (Fig. 30): This consists of non-pressurized tank with a hand pump (piston-type) fitted by its side. The capacity of tank varies between 6 to 16 or even 20 liters. The pump sucks the solution from tank which is then discharged through the lance and nozzles attached to the delivery pipe. It is carried on the back and held in position by means of two straps. Hold lance in one hand (right) and pump with the other hand (left). One man can spray about half a hectare in one day. In case of young crop or seedlings the single nozzle can be replaced by a double nozzle or even by a cluster of 3 to 4 nozzles and then a person can spray one hectare in a day. This sprayer is good for spraying water dispersible or wettable powder formulations of various pesticides.

HAND COMPRESSION SPRAYER (Fig. 30): This is an improved knapsack sprayer. There is a vertical hand-pump fitted in the tank. The cylindrical tank is usually of brass with a variable capacity upto 20 liters. It is filled three-fourth with spraying solution and in top one-third portion air is compressed. Then it is taken on the back and holding the lance in one hand, it is quite easy and comfortable to spray about half a hectare in one day. The only draw-back is that this sprayer is not suitable for using wettable or water dispersible powders, as there is no agitating mechanism provided in this sprayer.

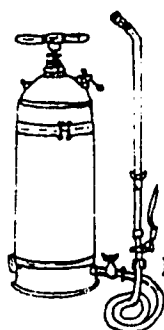
FOOT SPRAYER (Fig. 30): There is no tank in this sprayer. The pump is fitted on an iron stand and a pedal is attached to the plunger rod. There is a suction pipe (with strainer) fitted at the lower end which is dropped into the bucket containing the spray material. At the other end of the pump is a long delivery pipe fitted with a lance and a nozzle. Keep a foot on the pedal and press it down then release it, to come up again. With each upward movement of the pedal, the spray solution is sucked up into the pump chamber and with the downward motion of the pedal, the solution is discharged. At least 2 persons are required, one to pedal and other to hold lance and spray. Two more persons may be kept to fetch the water and prepare spray solution. They can easily spray about 2 hectares in one day.



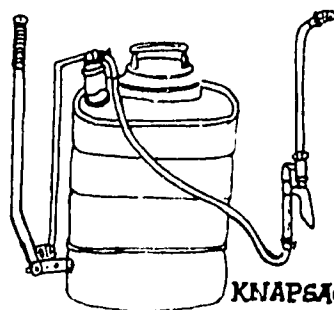
HAND CONTINUOUS SPRAYER



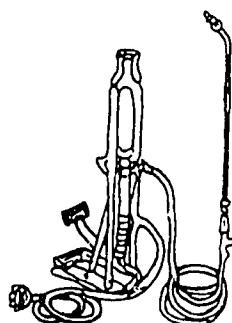
HAND SPRAYER



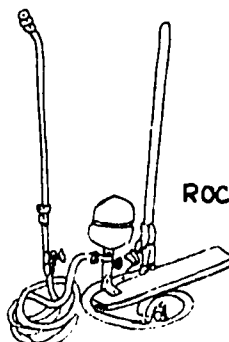
HAND COMPRESSION SPRAYER



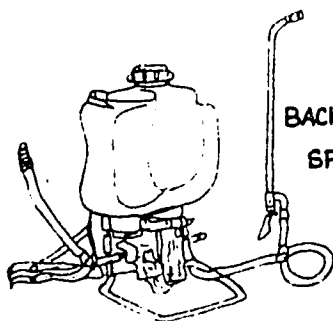
KNAPSACK SPRAYER



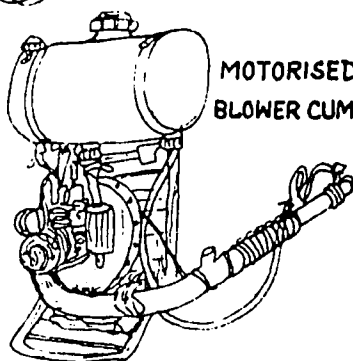
FOOT SPRAYER



ROCKING SPRAYER



BACK PACK SPRAYER



MOTORISED MIST BLOWER CUM DUSTER

Fig. 30. PESTICIDE APPLIANCES

ROCKER SPRAYER (Fig. 30): The principle is same as in pedal sprayer. In this, instead of pedal there is a long handle to be moved to and fro with hand. The pump along with brass chamber is fitted on a wooden board. The rocking movement, sucks the solution through suction hose and releases it through the delivery pipe as in case of pedal sprayer. Usefulness and man-power requirement is also same. It is only matter of choice, whether one wishes to pump with hand or foot. This is cheaper than pedal sprayer, but pedal sprayer is more popular.

MIST BLOWER (Fig. 30): This is a power-operated gaseous-energy knapsack sprayer which can be used for dusting as well as spraying. The hopper or tank is made of high-density polyethylene and has a capacity of 8 to 12 litres. Another small tank of one to two litres capacity is provided for fuel. The engine is generally 1.25 to 2.5 H.P. and is mounted on a frame with rubber packings to prevent the communication of vibrations of the engine to the person carrying it. There is a wide bore hose connected with the blower outlet; this is fitted with a cut-off cork. A drain-out pipe for the dust or a nozzle (with delivery tube) for spraying can be fitted to this hose connecting it with the hopper and the blower used for dusting or spraying. This is a low volume sprayer. Spray liquid is blown out by an air current generated in the machine. Due to high pressure droplets size is very small ranging from 50 to 150 microns which easily stick to the plant surface and there is no run-off losses of chemical. Moreover, the water requirement is also less than half than required for conventional sprayings. A person can treat about 3 hectares in one day.

DUSTING GUN (Fig. 31): A very simple type of plunger pump. The body is cylindrical, 45 to 60 cm long and 7 to 9 cm in diameter, made of some light metal or tin. The out-stroke of the pump sucks-in the air which passes into the duster chamber and the in-stroke causes the dust to blow out through the discharge outlet. Good for kitchen-gardens, nurseries and house-hold pests.

ORIENT HAND DUSTER (Fig. 31): This is a complicated appliance. The metallic dust container or hopper is connected to a blower (fan) through a suction pipe. It is provided with an agitator and a feeder. It is carried on shoulder by means of a strong strap. Hold the discharge tube in one hand (left) and rotate the crank-handle with the other hand (right). There will be continuous discharge of the dust. The quantity of dust discharge can also be adjusted. Though works very satisfactory, it is clumsy to carry and is therefore not so popular. A person can dust about a hectare in one day.

SOIL-INJECTOR (Fig.31): A hand pump also known as soil injecting gun. It has a long, pointed, metallic, hollow tube on one side. This rod has several openings. It is pushed into the soil to a depth of 12 to 15 cm and then the soil fumigant contained in the body of the pump is pumped into the soil. It is generally used for soil fumigation with volatile liquids like carbon disulphide, DD, EDB, etc. against nematode.

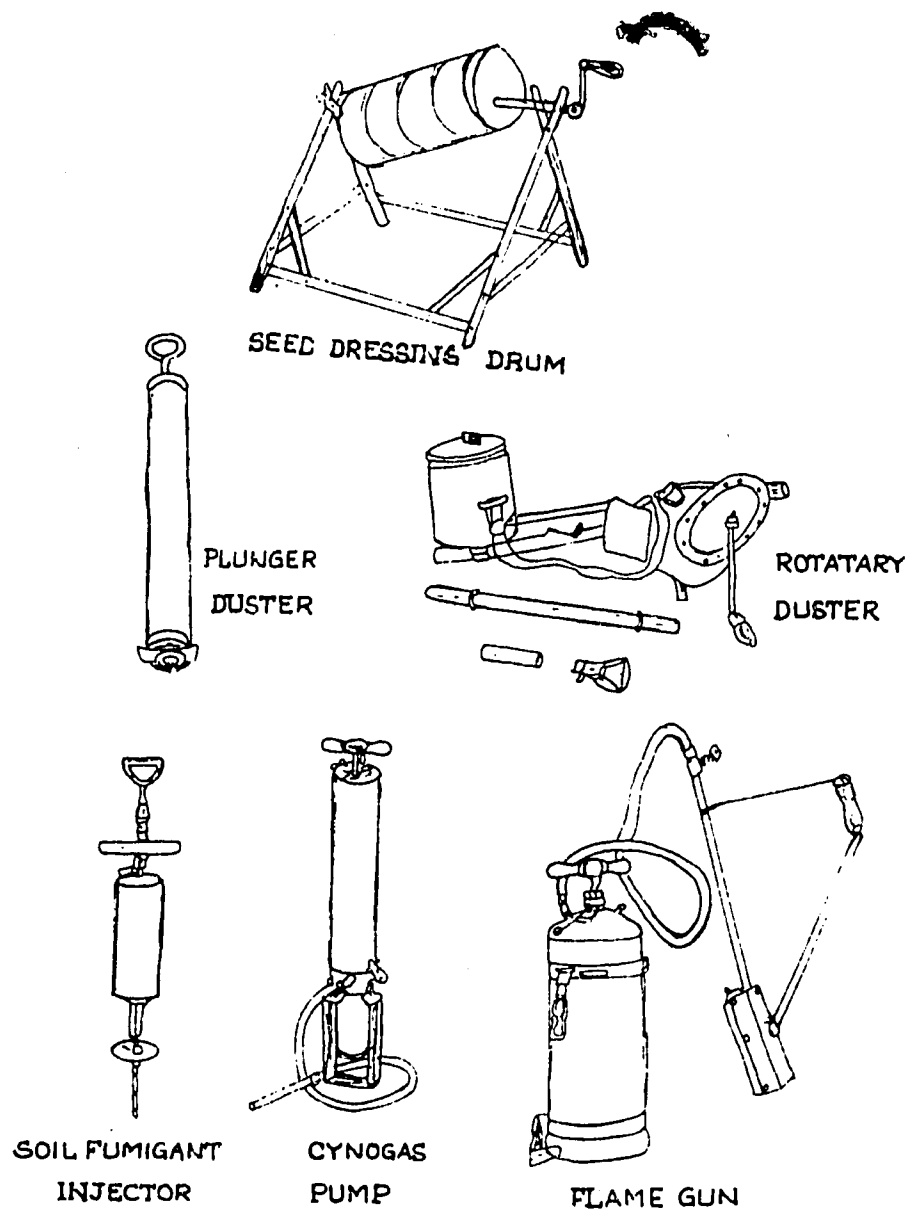


Fig. 31. PESTICIDE APPLIANCES

CYNOGAS FOOT-PUMP: (Fig. 31): Another plunger type pump for dusting the rat burrows. It has cylindrical brass body 40 to 50 cm long and 8 to 12 cm in diameter fitted with air pump on one side, glass or plastic container (dust chamber) on other side and a discharge tube (rubber hose) fitted with a valve. Working principle is same as that of dusting gun. When pumped into rat-burrows, calcium cyanide comes in contact with soil-moisture and liberates HCN gas which kills rats inside.

FLAME THROWER (Fig. 31): A knapsack type sprayer where the lance is fitted with a burner. The tank is filled with kerosene oil and compressed air. The burner is heated and oil allowed to flow through it, resulting in flames which are shot out. Used for killing locusts.

SEED-DRESSING DRUM (Fig. 31): A metallic drum of varying capacity (maximum 50 kg) is horizontally mounted (tilted slightly) on a stand. There are 3-4 iron-blades (baffles) fixed at the right angles to the inner surface of the drum which help in thorough mixing of the pesticide with seeds. The drum is rotated manually by means of a handle fitted at one end. Seed materials to be treated are put inside the drum along with appropriate quantity of chemicals with which the seed is to be treated. The drum is then rotated: 30 - 40 rotation (about 2 minutes) are enough to get the seed material uniformly coated with the chemical.

Calibration of a sprayer

Sprayer calibration is done to avoid excess or less amount of pesticide or to have an exact amount of spray liquid per unit area.

Every time before using a sprayer in field, calibration should be checked against manufacturer's data. If the data are not available, the sprayer should be calibrated to determine the spray amount at desired rate.

There are four factors governing the rate of delivery:

1. Swath width
2. Operator's speed
3. Size of nozzle aperture (orifice)
4. Air pressure.

Take a sprayer and clean it thoroughly. Fill the tank with water and check it if any leakage is there. Provide required pressure and measure the followings:

1. Swath width (m)
2. Operator's speed (m/min)
3. Liquid discharged (ml/min).

Formula:

$$\text{Amount spray required lit/ha} = x/y \times 10000$$

Where: x = spray amount over y area (ml)
 y = swath width (m) \times length of run (m/min)
1 ha = 10000 sq. meters

Example 1: A hand compression sprayer has a nozzle discharge of 1000 ml/min. Find out the amount of spray required/ha at a walking speed of 25 m/min with a swath width of 1 m.

Solution:

swath width = 1 m
length of run = 25 m /min
nozzle discharge = 1000 ml/min = 1 lit/min
Area of spray 1 m = 1 m x 25 m = 25 m² (y)
Amount of spray over y area = 1 lit (x)

Therefore, amount of spray req/ha = $\frac{x}{y} \times 10000$
= $\frac{1}{25} \times 10000 = 400$ litres

Example 2:

In the above example, calculate the number of run and time required to spray a hectare of land.

25 m² requires 1 run

Therefore, 10000 m² will require $\frac{1 \text{ run} \times 10000 \text{ m}^2}{25 \text{ m}^2} = 400 \text{ runs.}$

and because, 1 run requires 1 minute,

400 runs will require $\frac{1 \text{ min} \times 400}{60} = 6 \text{ hrs. } 40 \text{ min.}$

Parts of a hand compression sprayer

Hand compression sprayer is very popular in Nepal for the simple reason that it requires only one man to handle and do the spraying. It is quite robust and can withstand rough handling. The sprayer has following parts:

1. **Tank:** This is cylindrical in shape, usually made of brass and is used for holding the spray solution and compressed air. The size and capacity varies from 6 to 20 litres.
2. **Vertical air pump:** This comprises of a barrel which is a hollow tube fitted with a plunger shaft on upper side and an air-check valve assembly at its bottom. This assemblage comprises of a gasket washer, spring retainer, spring, valve case and air-check valve. The plunger shaft is an iron rod about one cm in diameter having a handle on the top end and a plunger bucket assemblage at the other end inside the barrel. The handle is provided with a locking device to prevent its vertical movement when the pump is not in use.
3. **Discharge tube:** This is a metallic tube about one mm thick, fitted in the tank to facilitate the spray solution to come out of the tank. At the free end inside the tank, it is fitted with a strainer. This tube with strainer should extend upto within 1.5 cm from the bottom of the tank.

4. **Filler-cap:** The sprayer has on the top of tank a hole called filler-hole for filling the spray solution in the tank. This hole is covered tightly by a lid called filler-cap or filler-hole-cap. It is fitted with a suitable oil and chemical resistant washer, so that when closed the tank becomes air-tight.
5. **Delivery hose:** A rubber, plastic or nylon pipe whose one end is fitted on discharge tube outlet and the other on cut-off cock using hose couplings and clumps. The hose being flexible can be turned in any direction to facilitate the spraying.
6. **Cut-off cock:** A small device usually made of brass, to regulate the flow of the spray fluid. This is usually spring-activated (trigger control) and is fitted with a valve inside. The spraying solution comes out only when the trigger is pressed.
7. **Spray lance:** It is a small brass pipe, 50 to 90 cm long, with screw-thread mechanism on both sides. Usually a cut-off device is fitted on one side and a nozzle on the other side. A good lance should have a diameter of not less than 6 mm and thickness of 0.6 mm.
8. **Nozzle:** This is a small accessory, usually cone-shaped and made of brass. It comprises of nozzle body, strainer, disc or orifice plate, washer, swirl plate and the cap. When in use, it breaks up the stream of spray fluid received from the lance and releases a fine mist of spray droplets through the hole at its tip.
9. **Pressure gauge:** Some sprayers are fitted with pressure gauge on top of the tank. It is a sort of meter indicating the air pressure inside the tank. Normally a pressure of 3 to 4 kg per sq cm is good enough for spraying; if it drops down, repumping may be done.
10. **Stand:** There is usually a 5 cm wide metallic (brass) or plastic skirt or band around the bottom of the tank to protect it from excessive wear and tear. It also serves as a stand when the sprayer is kept on the ground.
11. **Straps:** These are usually of mould-proof canvas belt about 4 to 6 cm wide with provision for quick adjustment of their length.

Care and maintenance of equipment

It is always necessary to keep the plant protection appliances neat, clean, dry and properly lubricated. This increases the life expectancy of the machines as well as facilitates their smooth working. Pay attention to the following points:

A. Before using:

1. Read the manufacturer's instructions carefully and follow the same faithfully.
2. The operator should endeavour to familiarize himself with the mechanism and working of the duster or sprayer, he is using.
3. Always keep an extra stock of washers and some spare parts that are usually easily worn out.
4. Have a tool kit handy.
5. Before taking the equipment to the field, check it thoroughly for any leakage, worn out washers or loose nuts. Better try spraying with water for a minute or two.
6. In order to apply the correct dose of insecticide per unit area the sprayer or duster should be properly calibrated.
7. The spray fluids should be thoroughly mixed and strained before putting in the tank. The dust must be dry and preferably sieved.
8. Only those formulations should be applied with a duster/sprayer, for which it is designed.

B. During usage:

1. See that air passage of the duster is not clogged with mud or soil.
2. Watch Nozzles for any inconsistency in the spray pattern, as also the blockage and leakage.
3. Keep an eye on pressure-gauge to ensure that the minimum required pressure is maintained.
4. When changing from one insecticide to other, the machine should be thoroughly cleaned. In case of sprayer flush it with water.
5. Delivery hose should not be bent or twisted while in use.

C. After use:

1. Empty the tank or hopper and clean it thoroughly.
2. Clean the machine. In case of duster, give a few turns with empty hopper to drive away all the dust etc. from the delivery pipe. For sprayers, spray with water for a minute or two, to remove the insecticides, if any, lying in the delivery pipe, lance or nozzle.
3. Store the equipment in a dry place.
4. Clean the equipment from time to time to keep it free of dust and dirt.
5. Do not leave lance and nozzles on bare ground.
6. If and when necessary, grease the plunger rods, washers, valves etc.
7. Overhaul the appliances regularly and replace immediately the worn-out parts. Specially at the end of season, inspect and examine all the wearing-parts like nozzles, pumps, valves washers, as also hose pipes. It is desirable to arrange the necessary replacement during the off-season to avoid inconvenience and delay when an equipment is required for use.

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